Cultivation of *Cannabis sativa* L. in northern Morocco

H. Stambouli, A. El Bouri, M. A. Bellimam, T. Bouayoun and N. El Karni

Researchers, Forensic Science Laboratory, Gendarmerie Royale, Rabat[*]

ABSTRACT

Field studies on cannabis cultivation have provided socio-economic data relating to, inter alia, production, yield and income. But only laboratory analyses of cannabis plants can provide information on their chemical composition and their levels of psychoactive constituents, thus enabling them to be classed as a drug type or a fibre type.

The present study, which covers cannabis in its fresh, dried and powdered forms, drew on fresh samples, obtained on the day they were harvested or immediately after preparation; that was done in order to prevent any alteration in the Δ-9-tetrahydrocannabinol (THC) caused by the oxidation that takes place as the product ages. The purpose of this study is to determine the THC level in 245 specimens obtained from 30 cannabis plots in three provinces of northern Morocco: Al Hoceima and Chefchaouen, where cannabis cultivation has a long tradition, and Larache, where cannabis cultivation has started only recently.

Qualitative analysis using high performance liquid chromatography with diode array detection revealed the presence of both the acid and the decarboxylated form of the main cannabinoids, cannabidiol, THC and cannabinol, and gas chromatography/mass spectrometry was used for the characterization of minor cannibinoids.

Quantitative analysis using gas chromatography coupled with mass spectrometry made it possible to determine the average Δ-9-THC content of cannabis in its fresh form (0.5 per cent), its dry form (2.21 per cent) and its powdered form (8.3 per cent). The results show that the traditional areas of cannabis cultivation—Al Hoceima and Chefchaouen—produce cannabis with a higher Δ-9-THC content than the Larache region.

In addition, the present study establishes that male plants, often considered deficient in Δ-9-THC, contain levels of the same order as those recorded for female plants, both in the leaves and in the tops.

Keywords: *Cannabis sativa* L; Δ-9-tetrahydrocannabinol; gas chromatography/mass spectrometry; high performance liquid chromatography with diode array detection

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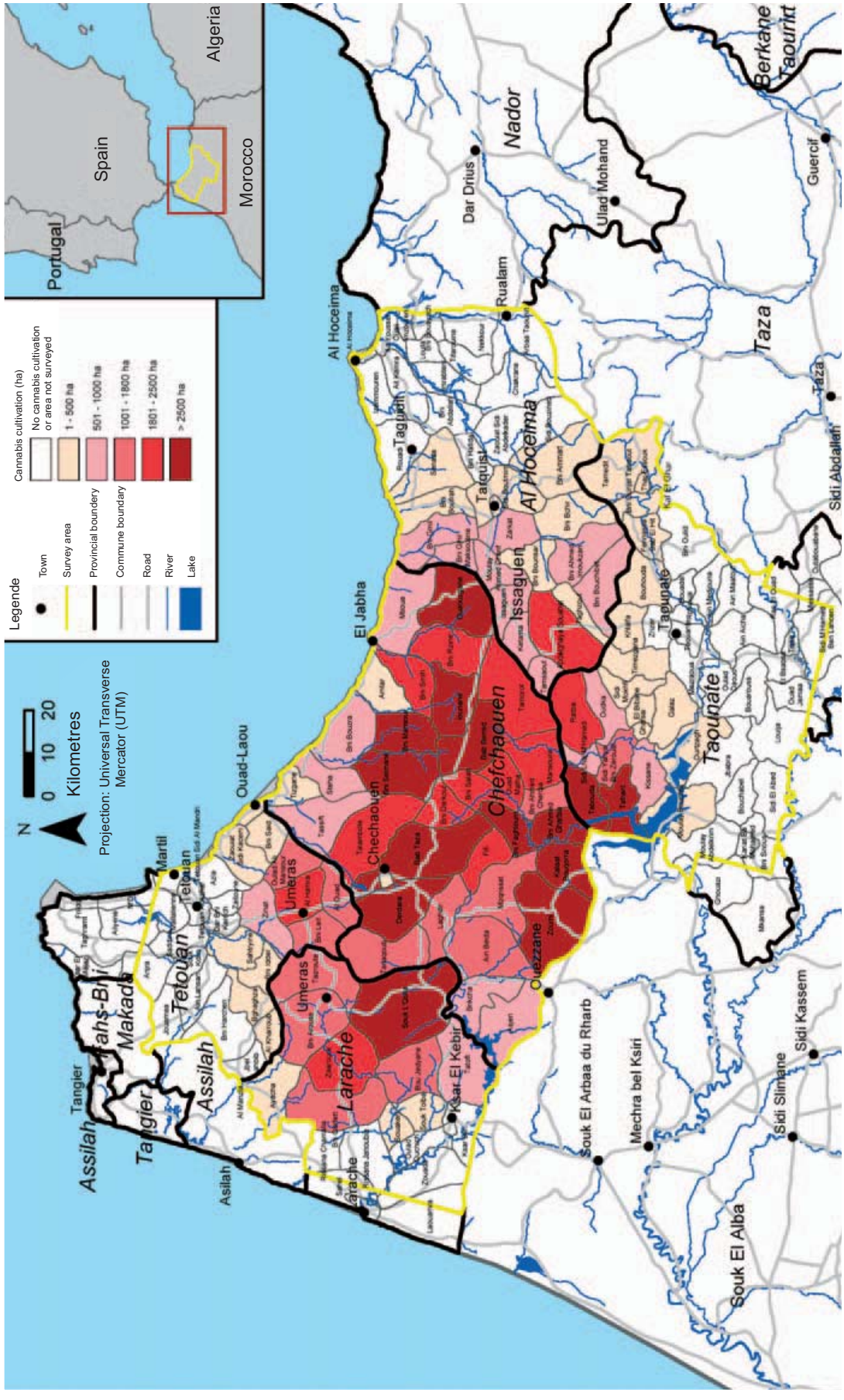
Figure I. Northern provinces of Morocco: cannabis cultivation, 2004



Source: United Nations Office on Drugs and Crime, *Morocco: Cannabis Survey 2003* (December 2003).

Note: The boundaries shown do not imply official endorsement or acceptance by the United Nations.

Introduction

The plant *Cannabis sativa* L. is grown widely throughout the world, in temperate and tropical countries. According to the *World Drug Report 2005* [1] of the United Nations Office on Drugs and Crime (UNODC), cannabis cultivation is widespread in Africa, the Americas, Asia and Europe. Identifying a total of 86 countries where the cannabis plant is grown, the *World Drug Report 2005* states that world cannabis production in 2004 was 47,000 tons, compared with 687 tons of cocaine and 565 tons of heroin. A total of 7,206 tons of cannabis products were seized in 2003, which is 15 times the total of cocaine seized and about 65 times the total of heroin seized.

Cannabis cultivation in Morocco, particularly in the central Rif, dates to the seventh century. Originally confined to a largely mountainous area, cannabis cultivation now takes place in the traditional growing areas of Chefchaouen and Al Hoceima – in the central Rif – and in recently designated extension areas north-west of Tetouan and Larache and south-east of Al Hoceima (figure I).

To evaluate the levels of THC of cannabis grown in Morocco, a study was conducted in three northern areas that together accounted for more than 80 per cent of the country's cannabis production in 2004 (figure II). The first, the Al Hoceima area of the central Rif, is characterized by small plots of land on hilly

Figure II. Distribution of cannabis production in the northern provinces of Morocco, 2004

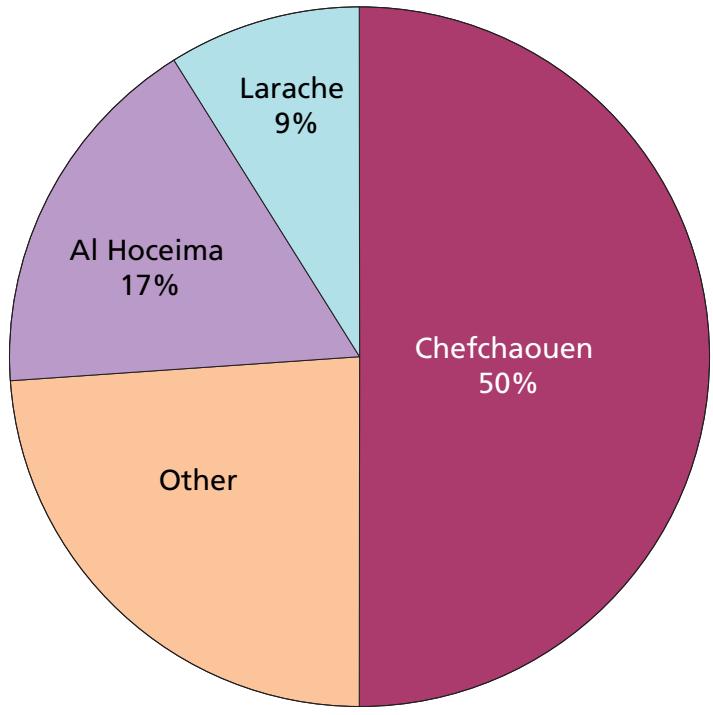


Figure III. Widespread use of traditional agricultural methods

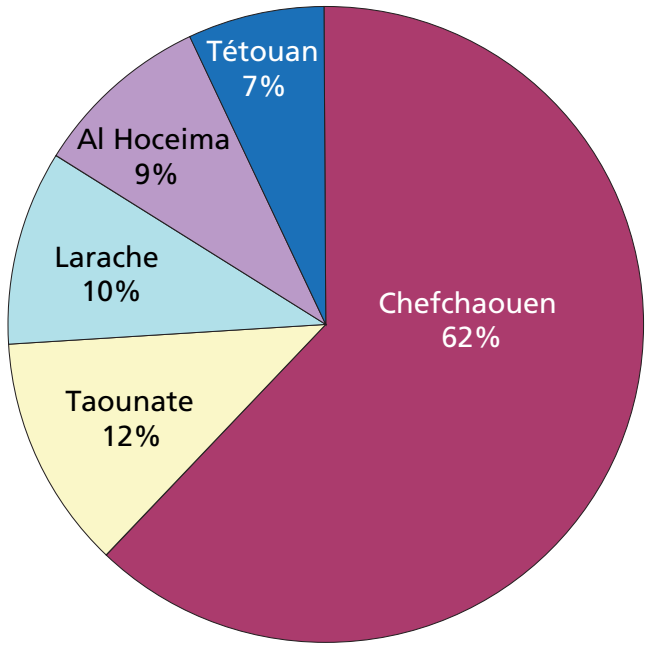
terrain where rudimentary agricultural techniques are still used (figure III). The second area is Chefchaouen, which was extended with the encouragement of the Protectorate in 1912 to pacify the rebel tribes of Ketama. The third area, situated in the Larache plain, was designated an extension area for cannabis cultivation 20 years ago, and modern production methods are used there.

The aim of this study, which was conducted in the framework of a partnership between the Agency for the Promotion and the Economic and Social Development of the Northern Prefectures and Provinces of Morocco (APDN) and the Forensic Science Laboratory of the Gendarmerie Royale, was to assess the quality of the cannabis produced in northern Morocco and determine the levels of the psychoactive constituent Δ-9-tetrahydrocannabinol (THC) for the different growing areas. The study was carried out pursuant to a cooperation agreement concluded with UNODC in February 2004, complementing a study carried out in the northern areas of Morocco in 2003 that focused on socio-economic data related to cannabis cultivation in the country.

Synthesis of social-economic data

The territories where most cannabis cultivation is located [2] total about 20,000 square kilometres, or 2.7 per cent of the total surface area of Morocco (figure I). It is estimated that in 2004, cannabis crops were grown on a total of 120,500 hectares (ha), with the largest cultivation area (figure IV) found in Chefchaouen (75,195 ha, or 62 per cent of the total cultivation area), followed

Figure IV. Distribution of total land area under cannabis cultivation in Morocco, by province, 2004

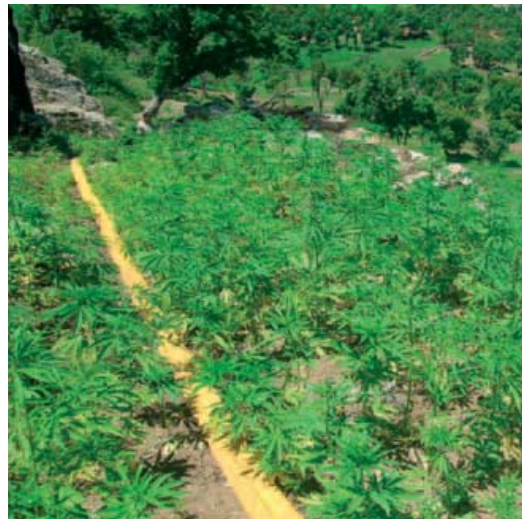


by Taounate (14,718 ha, or 12 per cent), Larache (11,892 ha, or 10 per cent), Al Hoceima (10,524 ha, or 9 per cent) and Tetouan (8,225 ha, or 7 per cent).

Most agricultural land in Morocco (88 per cent) is not irrigated but rain-fed (bour), and the yield of cannabis herb is, on average, 750 kg/ha, depending greatly on rainfall, soil quality, the number of successive years of cultivation, the use of chemical fertilizers and climatic conditions. (Figures V and VI show non-irrigated and irrigated cannabis cultivation.)

Figure V. Non-irrigated (*bour*) cultivation

Figure VI. Irrigated cultivation



The crop, once it has been dried in the sun, is called kif. Kif is either sold (66 per cent) or converted into cannabis resin at the production site (34 per cent). About 100 kg of kif is required to obtain 1-3 kg of resin by pounding and shaking, sifting it through fine nylon netting and pressing at either ambient or an elevated temperature. The final product is a slab wrapped in cellophane. Pounding the dried plant produces three qualities of powder:

Average share of cannabis converted into powder (percentage)			*Overall average share of cannabis converted into powder (percentage)*
Quality 1	Quality 2	Quality 3	
1.04	0.94	0.84	2.82

The first-quality powder, which is called *sigirma*, is golden beige in colour, is produced through the reduction of the flowering tops and the inflorescences and is reputed to have a THC content of up to 20 per cent. The second quality, which is called *hamda*, also contains plant waste, giving it a greenish colour; more or less intensive sifting of this powder yields products of varying quality, with a THC content of 2-10 per cent.

The population of the areas under cannabis cultivation in Morocco accounts for 2.7 per cent of the country's total population; the population density of 124 inhabitants per square kilometre is high compared with the national average of only 34 inhabitants per square kilometre. The number of rural families engaged in cannabis cultivation is estimated to be 96,600, which translates into a total of about 800,000 people.

The average annual family income from the sale of cannabis products is about $2,200, while the annual sale value of cannabis resin from Morocco on

the international market is estimated to be $13 billion. The income from cannabis received by farmers of Chefchaouen and Al Hoceima provinces, where cannabis has long been cultivated, accounts for 62 per cent of their total income. In the province of Larache, by contrast, where cannabis cultivation is a recent phenomenon, only 15 per cent of the income of farmers is estimated to be from cannabis.

Literature on cannabis

Botany

Cannabis is a member of the Cannabinaceae family. It is a dicotyledon, herbaceous (a non-woody plant whose aerial part dies after fruiting), annual, apetalous (the flower has no corolla) and most often dioecious (the male plants are distinct from the female plants). The height of the plant varies between 60 cm for the smallest varieties and 7 m for the largest. Under optimum conditions, the average height is about 3 m. The leaves on the lower part and the middle of the stalk are palmate, that is to say, consisting of 5-7 unequal, elliptical segments with dentate margins. The plants are a fairly dark shade of green.

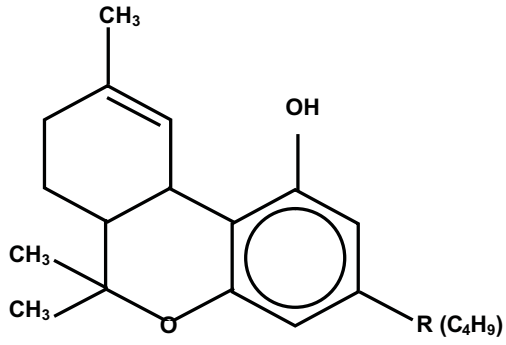
Cannabis is anemophilous, being pollinated only by the wind, but the male plants are often lifted young to prevent pollination of the female plants, in order to produce the sinsemilla variety, which is the only one used for the commercial production of cannabis herb, powder and resin.

The morphological, biological and pharmaco-chemical characteristics of cannabis depend on the growing conditions – altitude, temperature, humidity and light conditions – and the type of fertilizer used. As a general rule, crops grown in countries with a temperate climate contain only a small quantity of resin and thus have a low THC level. Indoor cultivation of cannabis plants can produce specimens with a high Δ-9-THC content.

Chemical composition

Several hundred different compounds have been isolated from cannabis [3], including terpene-based essential oils, flavonoids, sugars, fatty acids, phenolic spiro-indanes, dihydrostilbenes and nitrogenous compounds. The most interesting constituents, however, are the cannabinoids, found in the leaves and concentrated in the bracts and the resin. These are terpenophenols, classified in several groups according to their structure, the main ones being Δ-9-THC and its acid, cannabidiol (CBD) and cannabinol (CBN). These compounds are accompanied by homologues with shorter side chains (propyl and methyl cannabinoids), precursors (cannabigerol (CBG)) and chromane derivatives (cannabicyclol and cannabichromene), among others. In addition, R. Smith [4] has noted the existence of homologues with the butyl side chain C4H9 (figure VII), but at a concentration barely 1 per cent higher of that of pentyl homologues. The structures of those homologues (butyl-THC, butyl-CBD and butyl-CBN) were

Figure VII. Inferior homologues of Δ-9-tetrahydrocannabinol



determined by means of gas chromatography/mass spectrometry, using cannabis fractions concentrated by preparative thin-layer chromatography.

Active constituents

In addition to the usual constituents of a great number of plants, such as flavonoids and terpenes, more than 60 cannabinoids have been found to be present in cannabis. The main cannabinoids (figure VIII) having pharmacological effects on humans [5] include:

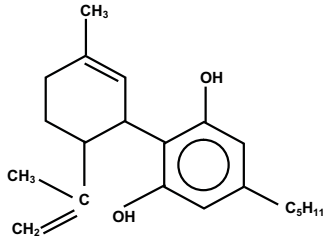
- Δ-9-THC, the product with the strongest psychoactive effect on humans;
- Δ-8-THC, which is less psychoactive than Δ-9-THC;
- CBD;
- CBN, which is not psychoactive but may have an anti-inflammatory effect;
- Δ-8-THC acid and Δ-9-THC acid (the latter is not active, but it is converted into Δ-9-THC when heated);
- CBG, which is not psychoactive but may have a bacteriological effect;
- Cannabichromene, cannabicyclol and their acids;

Cannabis varieties or chemotypes

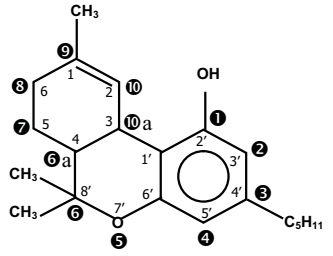
The varieties, or chemotypes, of cannabis depend on the biosynthesis of the cannabinoid constituents. The first stage in that process [6], shown in figure IX, is the condensation of geranyl pyrophosphate (I) with olivetol (II) to form CBG (III), the precursor of cannabichromene (IV), CBD (V) and Δ-9-THC (VI). Each stage is controlled by a specific enzymatic action [7-9] linked to the biogenetic factor that has an influence on the biosynthesis of the cannabinoids and on their abundance in the plant. Thus, there are different cannabis chemotypes: the drug type, the fibre type and the intermediate type. In practice, it is possible to distinguish between those chemotypes simply by determining the Δ-9-THC level [10].

Drug type, with a high Δ-9-THC content (>2 per cent). This type of composition may be observed in all cannabis plants that grow in hot climatic zones and produce a great deal of resin. There are many types of these plants, whose names differ from country to country.

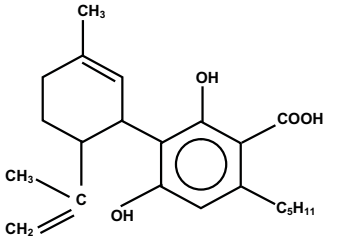
Figure VIII. Chemical structures of the principal cannabinoids characteristic of cannabis



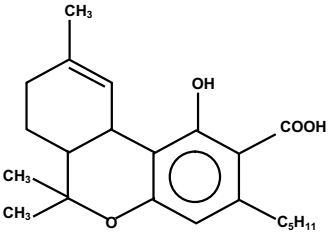
Cannabidiol
Synonym: CBD
$C_{21}H_{30}O_2$ = 314.5



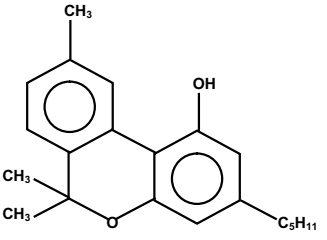
$\triangle^9$-Tetrahydrocannabinol
Synonym: $\triangle^1$-THC ; $\triangle^9$-THC
(-)-trans-$\triangle^9$-Tetrahydrocannabinol
$C_{21}H_{30}O_2$ = 314.5



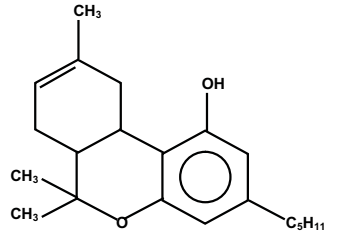
Cannabidiolic acid
Synonym: CBDA
$C_{22}H_{30}O_4$ = 358



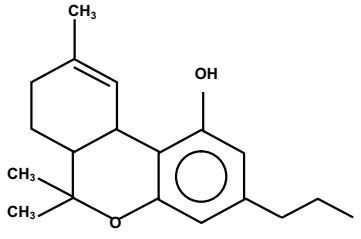
Tetrahydrocannabinol acid
Synonym: CBNA
$C_{22}H_{30}O_4$ = 358



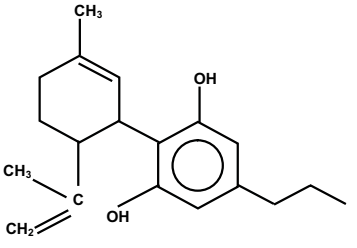
Cannabinol
Synonym: CBN
$C_{21}H_{26}O_2$ = 310.4



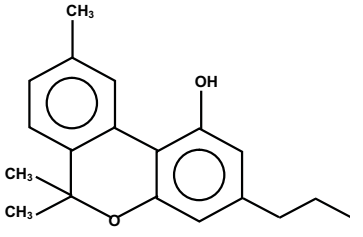
$\triangle^8$-Tetrahydrocannabinol
Synonym: $\triangle^{1\text{-}6}$–THC
(-)-trans-$\triangle^8$-Tetrahydrocannabinol
$C_{21}H_{30}O_2$ = 314.5



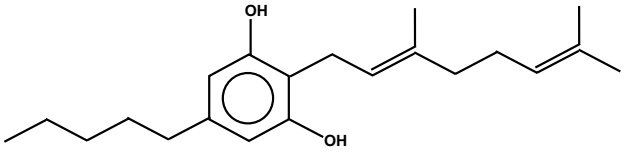
$\triangle^9$–Tetrahydrocannabivarin
Synonym: Cannabivarol
$C_{19}H_{26}O_2$ = 286



Cannabidivarin
$C_{19}H_{26}O_2$ = 286



Cannabivarin
Synonym: CBV
$C_{19}H_{22}O_2$ = 282



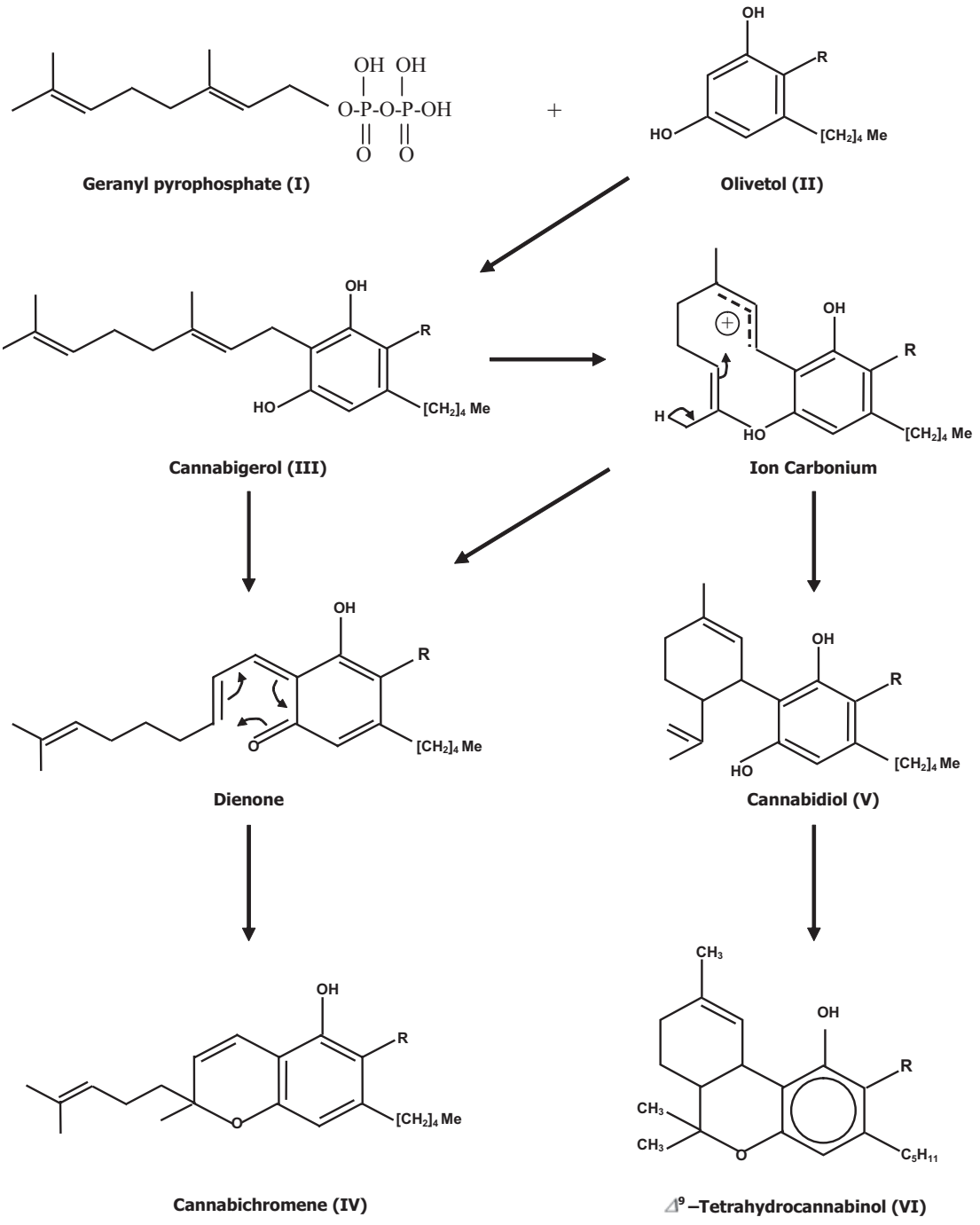
Cannabigerol
Synonym: CBG
$C_{21}H_{32}O_2$ = 316

Fibre type, with a very low Δ-9-THC content (<0.3 per cent) and a high CBD content. The plant is grown for the manufacture of special kinds of paper, non-woven textiles and animal litter. The Δ-9-THC content of most varieties grown in northern temperate zones for the manufacture of textiles does not exceed 0.03 per cent.

Intermediate type, high in Δ-9-THC (>0.5 per cent) and CBD (>0.5 per cent).

In the three chemotypes described above, the biosynthesis of the cannabinoids reaches completion. Recently, however, Fournier [11], has described a cannabis chemotype, the Santhica 23 and 27 varieties, in which biosynthesis stops

Figure IX. Biosynthesis of the principal cannabinoids



R = H, cannabinoid form
R = COOH, acid form of cannabinoid

at the CBG stage. The chemical composition of these varieties includes barely more than 0.1 per cent CBD, and they lack THC (both the acid and neutral forms of Δ-9-THC and Δ-8-THC). For that reason, they do not have any psychotropic properties. It is proposed that they be considered "second-generation fibre varieties". The chemical content of the three chemotypes [7] is summarized in table 1.

Table 1. Cannabinoid content of cannabis chemotypes [7]

	Compound content by chemotype (percentage)			
Cannabinoids	*Drug*	*Intermediate*	*Fibre*	
Δ-9-Tetrahydrocannabinol	>2	>0.5	<0.3	<0.1
Cannabidiol	—	>0.5	>0.5	<0.1
Cannabigerol	—	—	<0.1	>0.5

Different forms of cannabis

Stockley [12] describes several kinds of preparations based on the drug-type cannabis plant, whose shape, colour, consistency and other characteristics differ according to the country of origin. In particular, he describes a cannabis preparation derived from the compressed herb (marijuana) and one derived from the resin (hashish). The first takes the form of blocks of pulverized vegetable matter, including the various parts of the plant: the inflorescences, the leaves, the stalk and the seeds. When the males plants are lifted and the female plants are not pollinated, the resulting product, known as sinsemilla, has a high Δ-9-THC content. The second preparation, known as cannabis resin (or hashish), is, according to Stockley, made up of sticky, oily layers derived from the flowering tops of the plant, which are collected and compressed into blocks that can be malleable or hard, dry and powdery.

The slabs of cannabis produced in Morocco, known locally as *chira* or hashish and in Europe as cannabis resin, are produced by compressing the powder obtained by drying, pounding or sifting the dry female plant. They are stamped with a variety of marks (see figure X).

According to Mura and Piriou [13], kif (as it is called in Morocco), marijuana (in Canada and the United States of America) or takrouri (in Tunisia) is a mixture of flowering tops and leaves, dried and powdered, whereas, cannabis resin, also called hashish, is a compact brownish or yellowish powder that is obtained by pounding and sifting the dry leaves and flowering tops (see figure XI) and compressed into blocks (see figure XII).

Cannabis oil is a viscous liquid, greenish-brown to black in colour, with a characteristic smell. It is derived by extraction using 90-per-cent alcohol, followed by exposure to the sun to evaporate the alcohol. The liquid thus obtained is heated to solidify it, making it a marketable product. The oil has a Δ-9-THC content of 30-60 per cent.

Variations in the level of Δ-9-tetrahydrocannabinol in cannabis products

The differences in the level of Δ-9-THC found in various cannabis products can undoubtedly be attributed in large part to climatic and growing conditions. Factors such as hours of sunshine, temperature, humidity, altitude, maturity of the plant and the genetics of the sown seeds are particularly significant [14-20].

Figure X. Sample marks stamped on slabs of chira

The dried leaves of fibre hemp contain less than 0.5 per cent Δ-9-THC, whereas drug-type cannabis has a Δ-9-THC content of about 5 per cent, even 7-8 per cent. In the United States, a variety containing 15 per cent Δ-9-THC is produced in California, while cannabis grown indoors in the Netherlands

Figure XI. Pounding and sifting the dried cannabis plant

Figure XII. Cannabis resin packaged in various-sized slabs, stamped with a mark and wrapped in cellophane

produces cannabis resin containing up to 30 per cent Δ-9-THC [21]. However, lack of standardization of analytical laboratory procedures also results in data that may not be directly comparable. An overview of recent scientific studies on the subject is presented below.

A retrospective study of the Δ-9-THC content of cannabis confiscated in the United States between 1980 and 1997 [22], covering 35,213 samples of cannabis and its derivatives, taken from a total of 7,717 tons of confiscated products, showed that the average level of Δ-9-THC in samples of cannabis rose from 1.5 per cent in 1980 to 3.3 per cent in the period 1983-1984, staying at about the 3 per cent mark until 1992. After that, there was an upward trend, with the average level of Δ-9-THC rising from 3.1 per cent in 1992 to 4.2 per cent in 1997. The average Δ-9-THC in all cannabis products followed the same trend, rising from 3 per cent in 1991 to 4.47 per cent in 1997. In contrast, the average level of Δ-9-THC in cannabis oil did not follow any particular trend.

A study by the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA) [23] provides statistics on the levels of Δ-9-THC in cannabis herb and resin declared by European countries. According to the study, the most recent data, collected in 2001 and 2002, indicate a Δ-9-THC concentration of 1.6-15.2 per cent in cannabis herb and 2-20.6 per cent in cannabis resin.

A study in France [24] of 5,152 results of analyses conducted between 1993 and 2000 on cannabis-based products confiscated by customs officials, the police and the gendarmerie revealed wide variations in the concentration of Δ-9-THC in both cannabis herb and cannabis resin. In particular, 18 per cent of the samples analysed had a Δ-9-THC level below 2 per cent; until 1995, 75 per cent of the samples of cannabis herb had a Δ-9-THC level below 5.5 per cent; and 47 per cent of the samples of cannabis resin had a Δ-9-THC content of 5-10 per cent. Although that general trend continued after 1996, there was an exponential increase in products with an extremely high Δ-9-THC concentration. For example, it was noted that 3 per cent of the samples of cannabis herb and 18 per cent of the samples of cannabis resin in 2000 had a Δ-9-THC concentration greater than 15 per cent.

A study carried out in Greece [25] on 36 samples of cannabis herb seized during 1996 in the northern and southern parts of the country revealed a Δ-9-THC level ranging from 0.24 to 4.41 per cent in the north and 0.08 per cent and 3.41 per cent in the south. The study also drew attention to the difficulty of differentiating between the drug and fibre chemotypes of 20 per cent of the 36 samples analysed on the basis of the following ratios:

$$\frac{\%\ \Delta\text{-9-THC} + \%\ \text{CBN}}{\%\ \text{CBD}} \quad \text{or} \quad \frac{\%\ \Delta\text{-9-THC}}{\%\ \text{CBD}} \quad \text{and} \quad \frac{\%\ \text{CBN}}{\%\ \text{CBD}}$$

A study of the Δ-9-THC level in 220 cannabis products seized on entry into the United Kingdom of Great Britain and Northern Ireland between 1979 and 1981 [26] found that samples of cannabis herb had an average Δ-9-THC concentration of 1.0-8.5 per cent. The level for the cannabis resin seized was between 3.8 per cent and 21 per cent, the average value being in the range 5.8-12.5 per cent. The Δ-9-THC concentrations in three samples of cannabis resin probably of Moroccan origin were estimated in the study to be 6.8 per cent, 7.1 per cent and 8.2 per cent. Fairly similar concentrations were found in samples of cannabis resin that came from Lebanon, Pakistan and Turkey.

Lastly, the Forensic Science Laboratory of the Gendarmerie Royale determined that 30 samples of cannabis resin seized in Morocco in 2004 had an average Δ-9-THC content of approximately 6 per cent. The Δ-9-THC concentration of those samples varied within a range of 0.4-16.0 per cent, with a confidence interval of 4.5-7.5 per cent. Thus, there was wide variation in the content of Δ-9-THC on the market.

Study of cannabis in Morocco

Presentation of the study

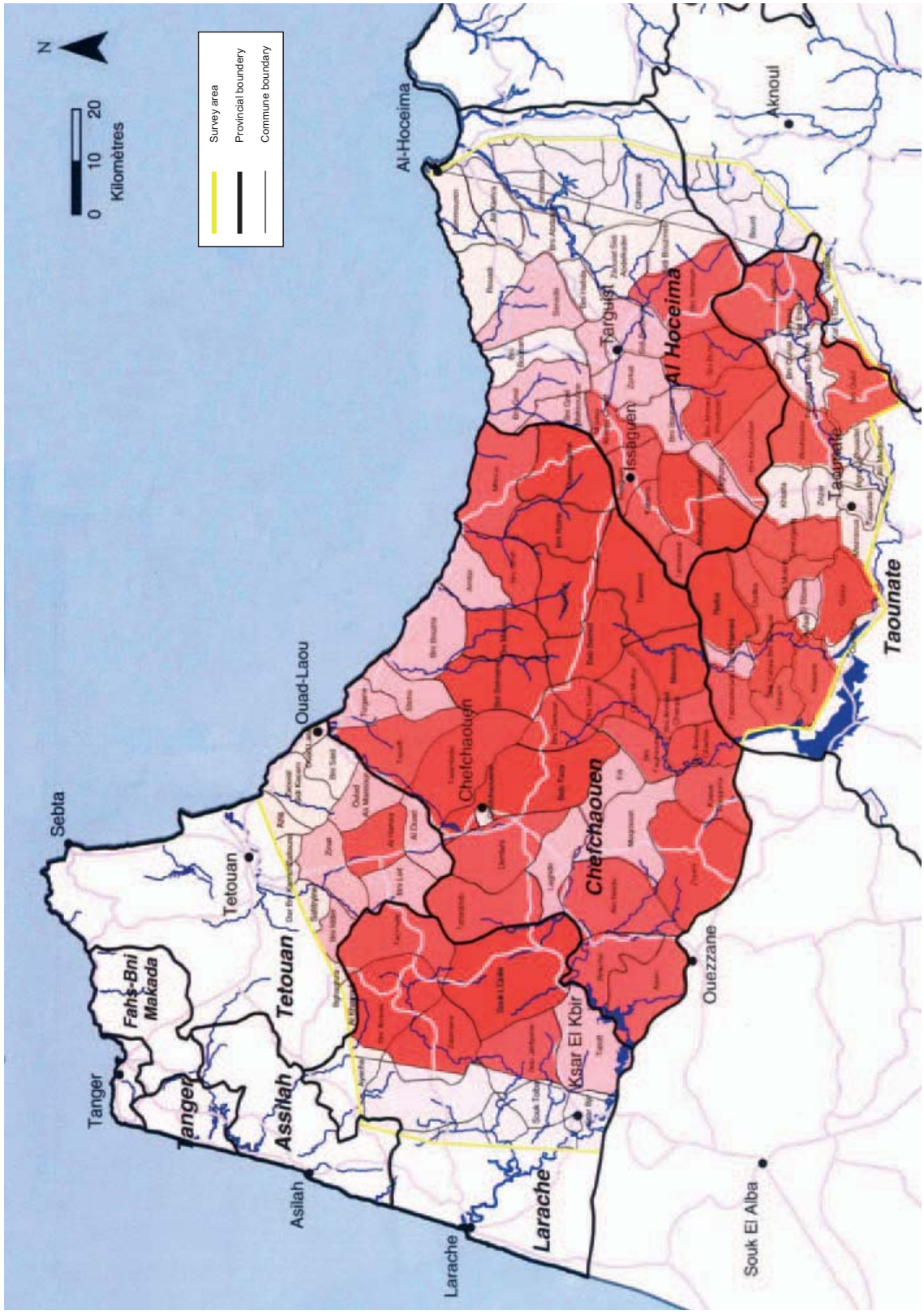
The purpose of the present study was to determine the chemical composition of various cannabis crops grown in northern Morocco and assess the levels of the psychoactive constituent Δ-9-THC found in them. The approach adopted was to subject Moroccan cannabis to qualitative analyses using high performance liquid chromatography with diode array detection (HPLC-DAD) and gas chromatography/mass spectrometry (GC/MS) and to determine, by means of GC/MS, the levels of the psychoactive constituent Δ-9-THC. The analyses were conducted on the growing (fresh) plant, the dry, mature plant and the powdered form obtained by drying, pounding and sifting, taking into account the contribution of the flowering tops and the leaves. In total, 245 samples of leaves and inflorescences were analysed: 180 samples of fresh male and female plants (inflorescences and leaves), 52 samples of dry female plants (inflorescences and leaves) and 13 samples of powdered plants. The THC concentrations in the male plants, which are usually removed early to prevent pollination, were determined and compared with those in female plants at the same stage of growth.

The study covered the areas of Chefchaouen, Al Hoceima and Larache (see figure XIII). The choice of plots took account of the traditional agricultural methods used in the Chefchaouen and Al Hoceima areas, where cannabis cultivation is a long-established practice, in contrast to the modern methods used in the Larache area, which was established two decades ago. The cannabis plants sampled came from both irrigated land, accounting for 12 per cent of the total area of cultivation, and unirrigated (*bour*) fields, which make up the remaining 88 per cent. In 2004, average raw cannabis production for those two forms of cultivation was 1,270 kg/ha and 750 kg/ha, respectively.

From an analytical point of view, it has been established that, while the qualitative analysis of cannabis poses no real difficulty, quantitative analyses aimed at determining the Δ-9-THC level in cannabis often entail the problem of the reproducibility of the results. That factor, which is liable to affect the accuracy of the values obtained, is due principally to the plant's heterogeneity: the flowering tops normally have a higher Δ-9-THC concentration than the leaves, while the stalks and the seeds do not contain Δ-9-THC. The lifting and sampling stages are therefore of great importance, and care was taken in the study not to neglect those stages but to try to assess their impact on the reliability of the concentration determinations. The study also took into account another influential factor: the drying process. Although several authors [11, 24 and 27] recommend the systematic drying of samples before analysis, at a temperature below 70° C for 6-8 hours, until a constant weight is achieved, the risk of losing Δ-9-THC due to the transformation process remains. One source [25] reports a loss of Δ-9-THC when cannabis is stored at temperatures above room temperature (37°-50° C).

Another difficulty lies in choosing the analytical technique that is most appropriate for determining the Δ-9-THC concentration: liquid or gas chromatography.

Figure XIII. Geographic distribution of plots studied



This study was conducted using GC/MS with autoinjector. That technique has the advantage of permitting the determination of the total Δ-9-THC, because the two forms, the psychoactive (Δ-9-THC) and the acid (THCA), are measured

simultaneously after decarboxylation of the acid [26] as a result of the high temperatures in the injection part of the gas chromatograph. Decarboxylation may continue even during elution of the analytical column, which is also heated to high temperatures (Tf = 280° C).

Materials and methods

Samples were taken from plots located in areas of Morocco where cannabis is traditionally grown (Chefchaouen and Al Hoceima) and the recently established cultivation area (Larache). The sowing of those plots took place over a period extending from February to May 2004, after which the Δ-9-THC levels in the crops of the three regions were monitored. Sampling was optimized by lifting a large number of plants from each plot and by taking material from the upper and lower thirds of each plant.

The study covered growing plants, mature plants dried in the sun and plants converted to powder form. A total of 245 samples of leaves and inflorescences from male and female plants were collected in the three regions:

- Samples of green, growing plants (a male and two female plants about 10 metres apart) were collected from the middle of 30 plots (13 in Chefchaouen, 8 in Al Hoceima and 9 in Larache).
- Bunches of dry plants were collected from 26 plots (10 in Chefchaouen, 8 in Al Hoceima and 8 in Larache).
- Several grams of powdered cannabis derived by drying, pounding and sifting the leaves and flowering tops were obtained from 13 plots (5 in Chefchaouen and 8 in Al Hoceima). No samples of powdered cannabis were available in the Larache area, where the conversion of dry plants into powder is believed to be still uncommon.

Table 2. Summary of cannabis samples, 2004 growing season

Province	*Green plant (sampling date: 21 July 2004)*	*Dry plant (sampling date: 10 Sept. 2004)*	*Powdered plant (sampling date: 10 Sept. 2004)*
Chefchaouen	13	10	5
Al Hoceima	8	8	8
Larache	9	8	—
Total	30	26	13

Analytical procedure

For the extraction of the samples, use was made of organic solvents and standards of analytical quality. Extractions were carried out in a 9:1 methanol/chloroform solution with a 0.05 g/l nonadecane internal standard.

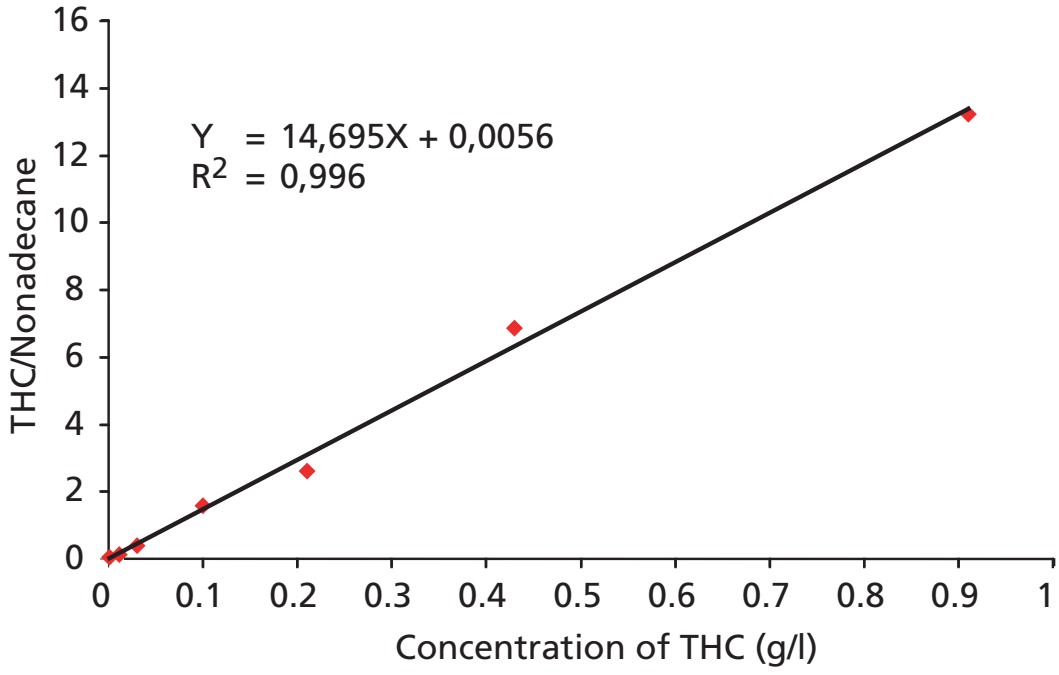
In the case of the fresh plant, two distinct types of samples were taken and analysed separately. The first type consisted entirely of flowering tops, and the

second of a one-to-one mixture of leaves taken from the lower and upper extremities of the plant. The samples, wrapped in aluminium paper, were immersed in liquid nitrogen. They were then crushed, and a test specimen of 100 mg was soaked in 3 ml of extraction solution. In the case of the dry plant, leaves from the lower and upper extremities and flowering tops were removed separately. They were ground, and a test specimen of 15 mg of each powder thus obtained was soaked in 3 ml of extraction solution. For powdered cannabis, a test specimen of 10 mg was taken directly after homogenization and soaked in 6 ml of extraction solution. The extractions were made by sonication for 30 minutes. The resulting solutions were dried over magnesium sulfate and filtered, and 1 μl of each solution was injected into the GC/MS system, or 20 μl was injected into the HPLC system.

Internal standard

The Δ-9-THC level in the cannabis plant and powder was estimated using the internal standard method. The calibration curve was obtained by injecting into the GC/MS system 1 μl of seven standard solutions of Δ-9-THC in concentrations of 0.65-0.91 g/l, again with a 0.05 g/l nonadecane internal standard. The correlation coefficient of the curve (see figure XIV) is 0.996.

Figure XIV. Calibration curve of Δ-9-tetrahydrocannabinol



Instrumentation

The analyses by means of liquid chromatography (HPLC-DAD) were carried out using a Merck L-5025 injection system, a Hypersil column ODS (100 mm × 4 mm × 3 μm), a Merck Hitachi L-3000 diode array detector and a Merck L-6200 A

pump. The mobile phase used was a 0.02 M acetonitrile/water/0.02 M sulphuric acid mixture, in the proportions 70:20:10, with a flow rate of 1 ml/min.

The GC/MS analyses were carried out using a Varian CP-3800 gas chromatograph coupled with a Saturn 2200 ion trap mass spectrometer, equipped with a CTC Analytics CombiPAL automatic sampler and a PTV 1079 injector.

Separation was carried out using a 5 per cent phenyl methyl siloxane capillary column (HP-5) (25 m × 0.2 mm × 0.11 μm), with helium as the carrier gas. A 22-minute oven temperature programme was adopted: Ti 60° C (2 min), temperature ramp 15° C/min, Tf 280° C (5 min). The injector, operating in the splitless mode, was set at an isothermal temperature of 270° C.

Mass spectrometry was carried out using 70 eV electron impact over a mass range of 35-500 amu. The trap temperature was 180° C and the transfer line temperature was 280° C.

Results and discussion

Qualitative analysis

A qualitative analysis was carried out on each of the three forms of the plant, fresh, dry and powdered, using GC/MS and HPLC-DAD. GC/MS is suitable for dealing with the plant's thermally stable compounds, while HPLC-DAD, being more sensitive, registers even the thermally labile acid forms and thereby gives a better idea of the real cannabinoid composition of the plant (acid forms and decarboxylated forms).

The GC/MS-type chromatographic profiles did not indicate any dissimilarities between the products of the regions studied in any of the three plant forms. GC/MS revealed (see figure XV) a terpenic fraction eluting before the nonadecane internal standard and a fraction of cannabinoids, the most characteristic of which were Δ-9-THC, CBD and CBN in trace amounts. Their retention times were 14.920 min, 14.380 min and 15.293 min, respectively.

A series of other cannabinoids was revealed by reconstitution of the specific ions from the total ion current. The presence of inferior homologues of the plant's active constituent (methyl-, ethyl-, propyl- and butyl-THC), along with its natural precursors (cannabigerol, cannabichromene, cannabivarin and others), was noted (figure XVII). In addition, as reported in the literature [18, 28-31], three natural THC isomers were present: trans-Δ-8-THC, cis-Δ-9-THC and trans-Δ-9-THC (figures XVI and XVII). Although the trans-Δ-8-THC form was the most thermodynamically stable, the trans-Δ-9-THC form was the most common. Those three isomers, having similar mass spectra, were identified by their respective retention times (14.17 min, 14.61 min and 14.920 min). That sequence in the order of elution has been partially described by R. Smith [4].

Lastly, GC/MS analysis makes it possible to trace the natural development of Δ-9-THC from cannabidiol from the time that the green plant is growing to the dry plant stage (see figure XVIII, which shows a variation in opposite directions of the intensity of peaks 2 and 3 on chromatograms A and B) and also

Figure XV. GC/MS-profile of the organic extract from the dried cannabis plant and mass spectra of the principal cannabinoids

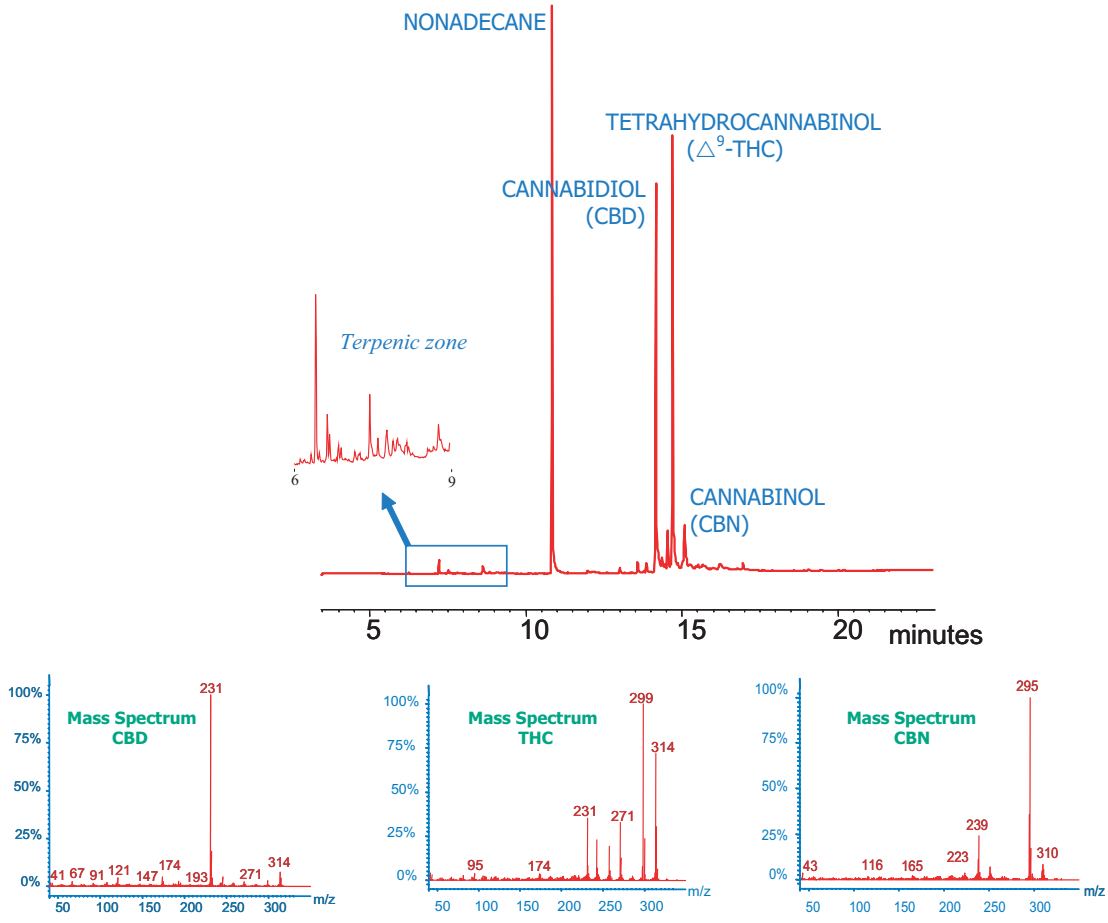
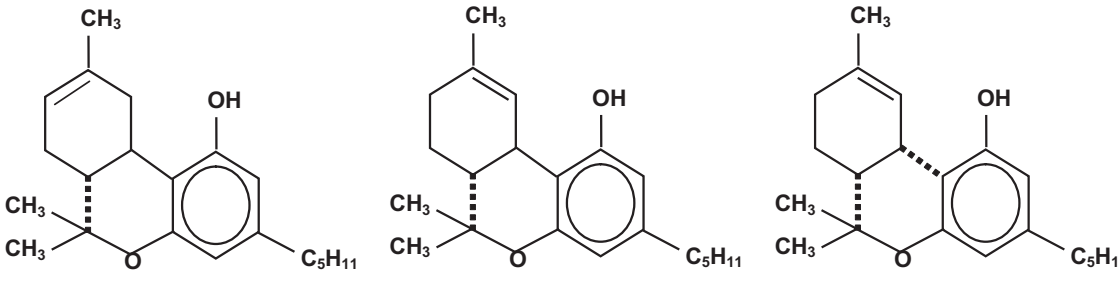
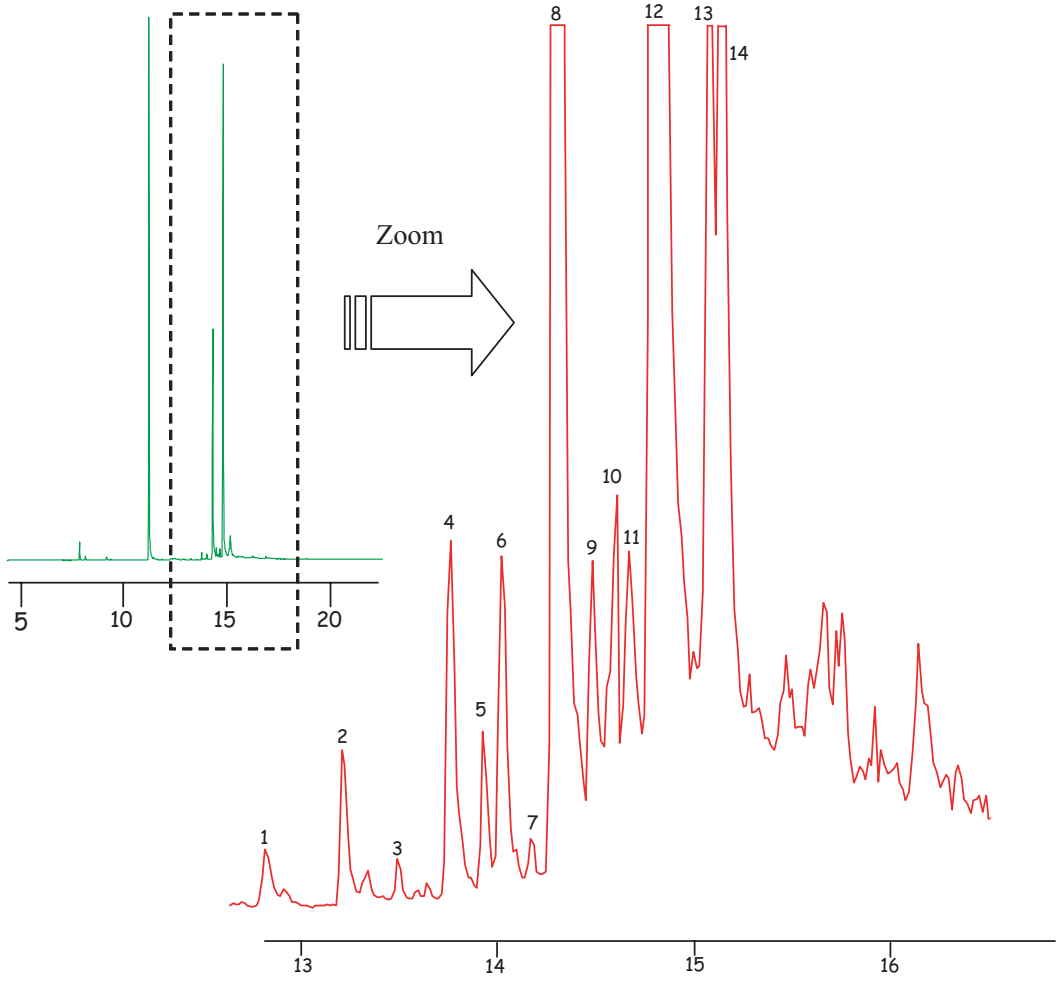


Figure XVI. Chemical structures of the natural isomers of tetrahydrocannabinol present in Moroccan cannabis



Trans-Δ^8-Tetrahydrocannabinol Trans-Δ^9-Tetrahydrocannabinol Cis-Δ^9-Tetrahydrocannabinol

Figure XVII. Determination by gas chromatography/mass spectrometry of the cannabinoids present in *Cannabis sativa* L. in powdered form

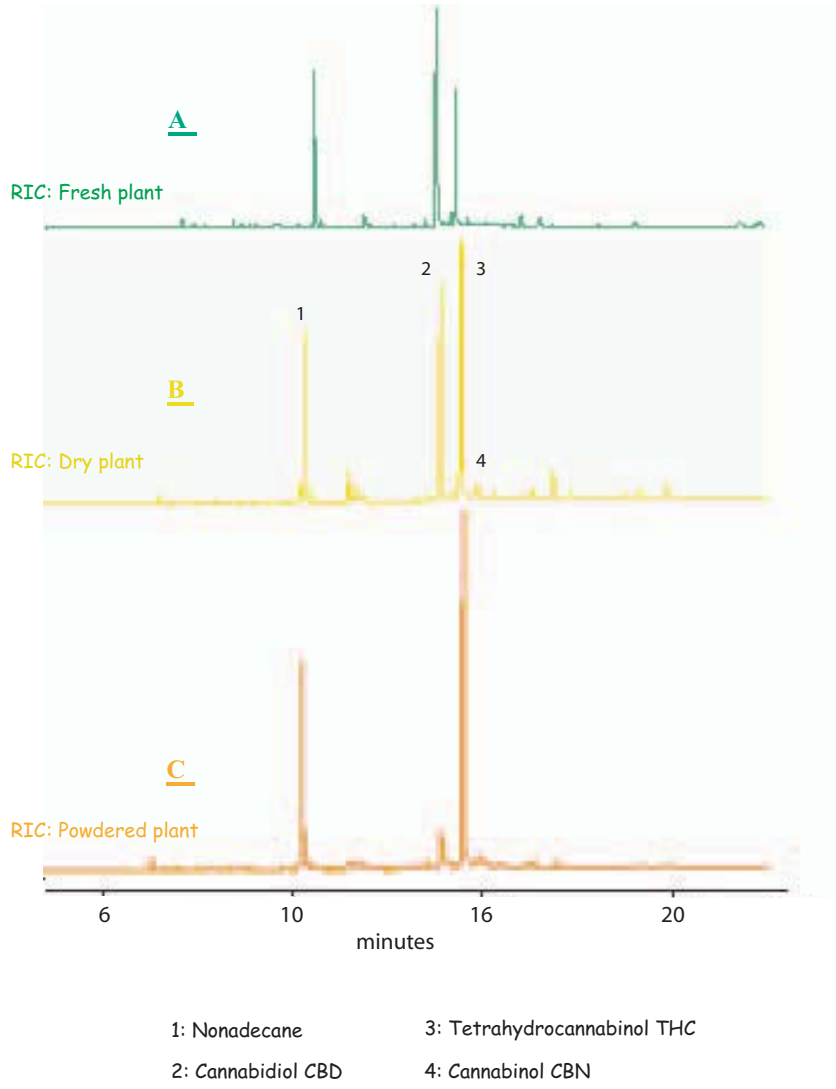


1 : Methyl-tetrahydrocannabinol m/z = 358
2 : Cannabivarol m/z = 386
3 : isomer CBD m/z = 314
4 : Tetrahydrocannabivarin m/z = 386
5 : Butyl-tetrahydrocannabinol m/z = 300
6 : Cannabichromene m/z = 314
7 : Trans Δ^8 -THC m/z = 314
8 : Cannabidiol m/z = 314
9 : Cannabicoumaronone m/z = 328
10 : Cis Δ^9 -THC m/z = 314
11 : Hydroxy-tetrahydrocannabinol m/z = 330
12 : Trans Δ^9 -THC m/z = 314
13 : Cannabigerol m/z = 316
14 : Cannabinol m/z = 310

the increase in Δ-9-THC in cannabis powder as a result of the preparation process (see figure XVIII, which shows the increase in the relative intensity of peak 3 as between chromatograms B and C).

HPLC-DAD analysis was carried out to determine the levels of the major cannabinoids contained in the cannabis and to trace their development from the growing plant stage to the stage of maturity and following the plant's conversion into powder. The presence of the two principal cannabinoids, THC and CBD, with traces of CBN, was observed, as expected; most notable, however, was the clear dominance, at various stages of the plant's growth, of the acid forms cannabidiolic acid (CBDA), cannabinolic acid (CBNA) and

Figure XVIII. Evolution of the GC/MS profile of the organic extract from cannabis in fresh, dry and powdered form

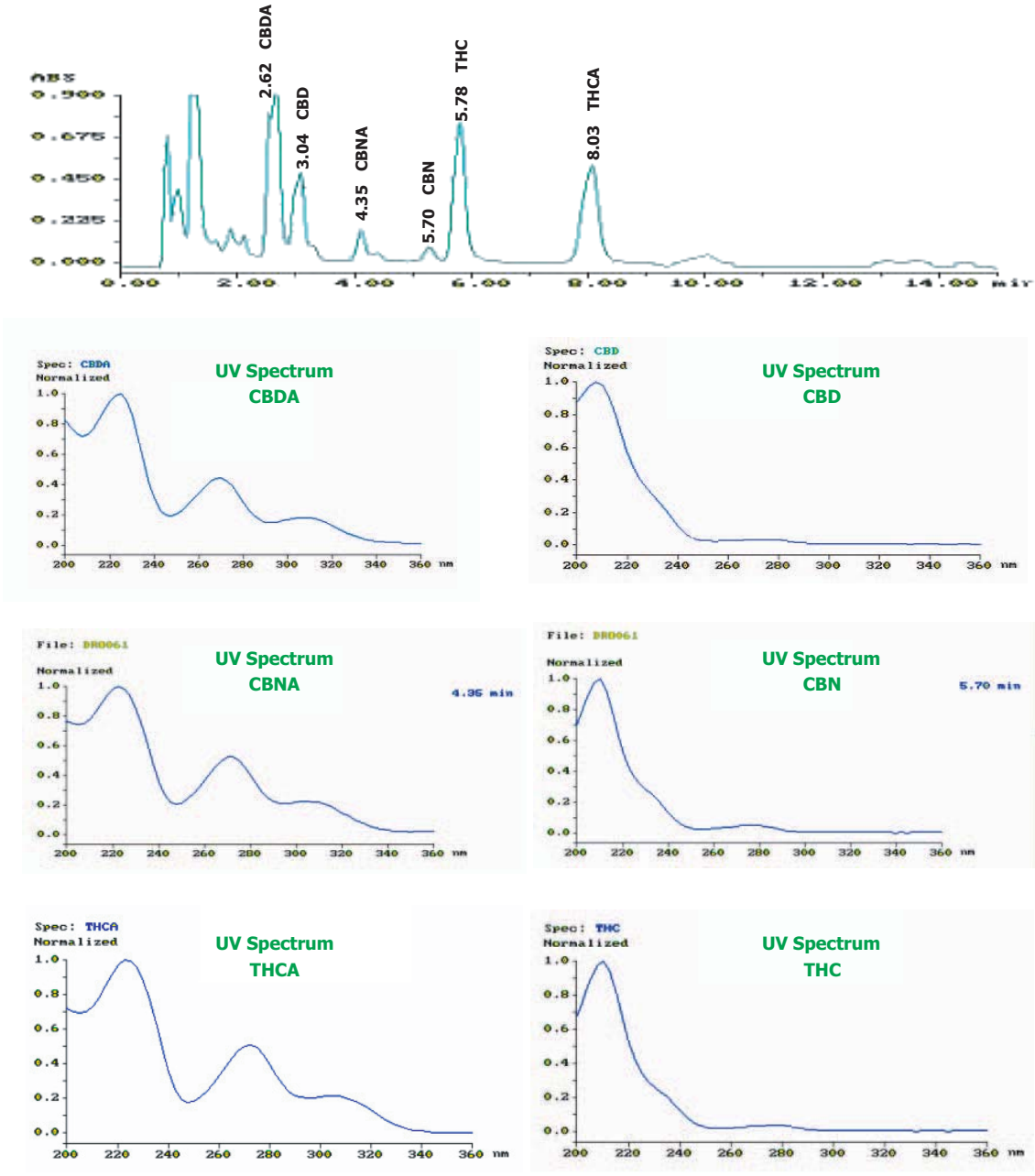


Δ-9-tetrahydrocannabinolic acid (THCA), which were not detectable by GC/MS (see figure XIX). The same results were obtained for all samples from three areas.

Quantitative analysis

The GC/MS analysis of organic extracts from the cannabis plant was used in determining the thermally stable components THC, CBD and CBN and their respective acid forms THCA, CBDA and CBNA, which are decarboxylated under the effect of heat (injector and oven), giving the forms THC, CBD and CBN. The Δ-9-THC levels in the three sample types – the green plant, the dry plant and the powdered plant – were determined by applying the peak area ratio Δ-9-THC chromatographic peak area/internal standard area to the previously established calibration curve.

Figure XIX. Chromatographic profile of powdered cannabis obtained using high performance liquid chromatography-diode array detection and UV spectra of key cannabinoids and their acid forms



(CBD = cannabidiol; CBDA = cannabidiolic acid; CBN = cannabinol; CBNA = cannabinolic acid; THC = tetrahydrocannabinol; THCA = tetrahydrocannabinolic acid)

Determination of Δ-9-tetrahydrocannabinol levels in fresh cannabis plants

Female plants

The Δ-9-THC levels of the leaves of the fresh female plants varied from region to region (figure XX). The average levels were of the same order (0.4 per cent) in the three regions.

In the case of the flowering tops of the fresh plants, which had average levels of the order of 0.6 per cent (see figure XXI), the highest average concentrations were found in the samples from Al Hoceima (0.7 per cent) and Chefchaouen (0.6 per cent), compared with the samples from Larache (0.4 per cent).

More generally, a comparison between the average Δ-9-THC concentrations in the inflorescences and the leaves revealed, as expected, high concentrations in the inflorescences (figure XXII).

Figure XX. Average Δ-9-tetrahydrocannabinol content in the leaves of fresh female cannabis plants from three areas in Morocco

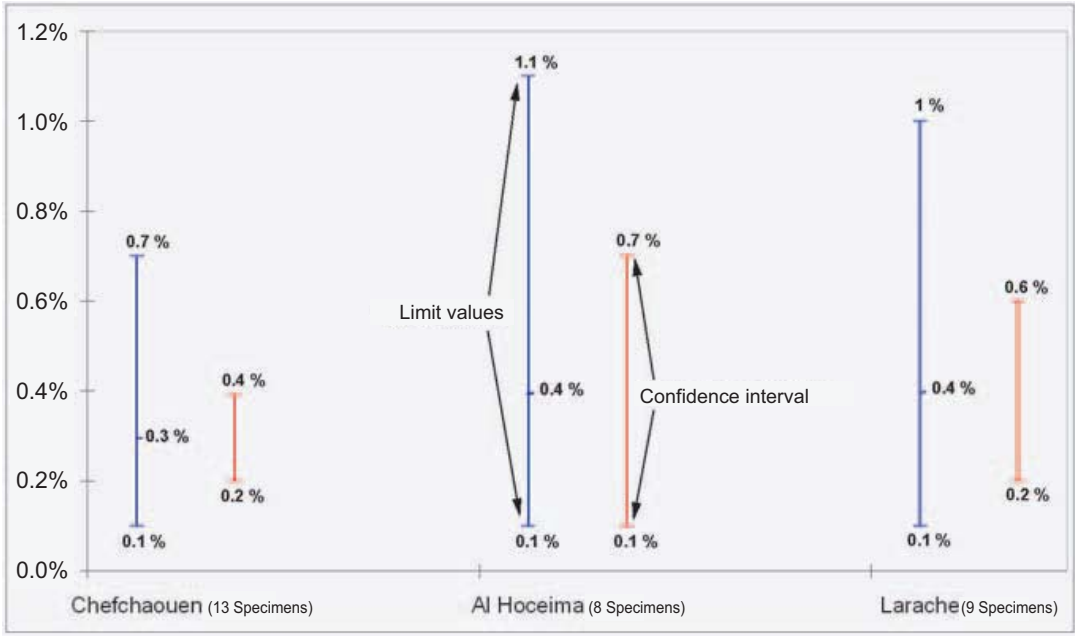


Figure XXI. Average Δ-9-tetrahydrocannabinol levels in the flowering tops of fresh female cannabis plants from three areas in Morocco

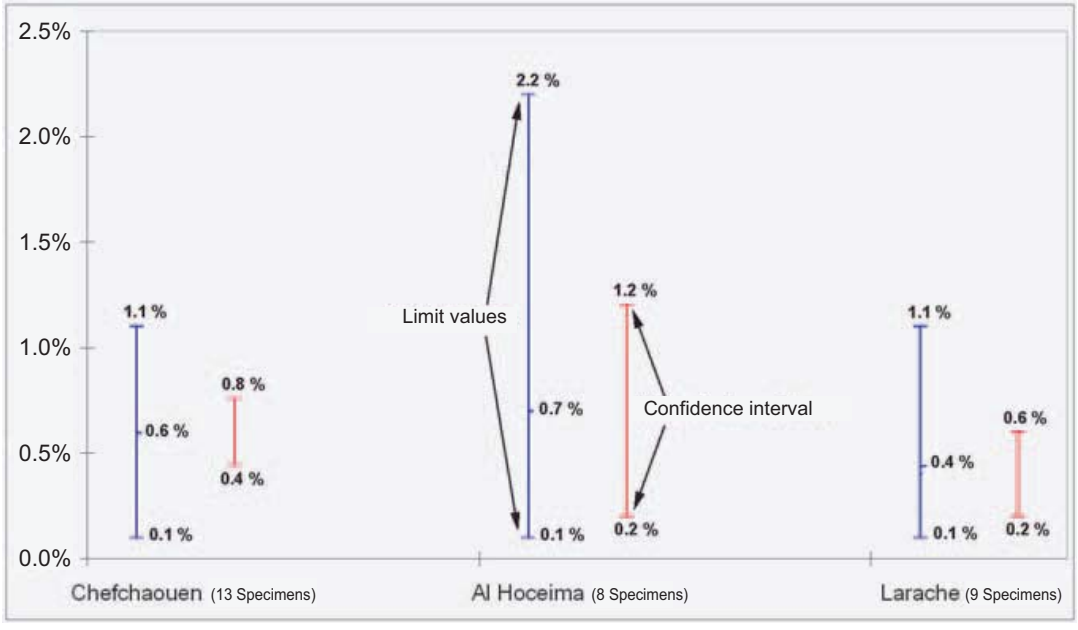
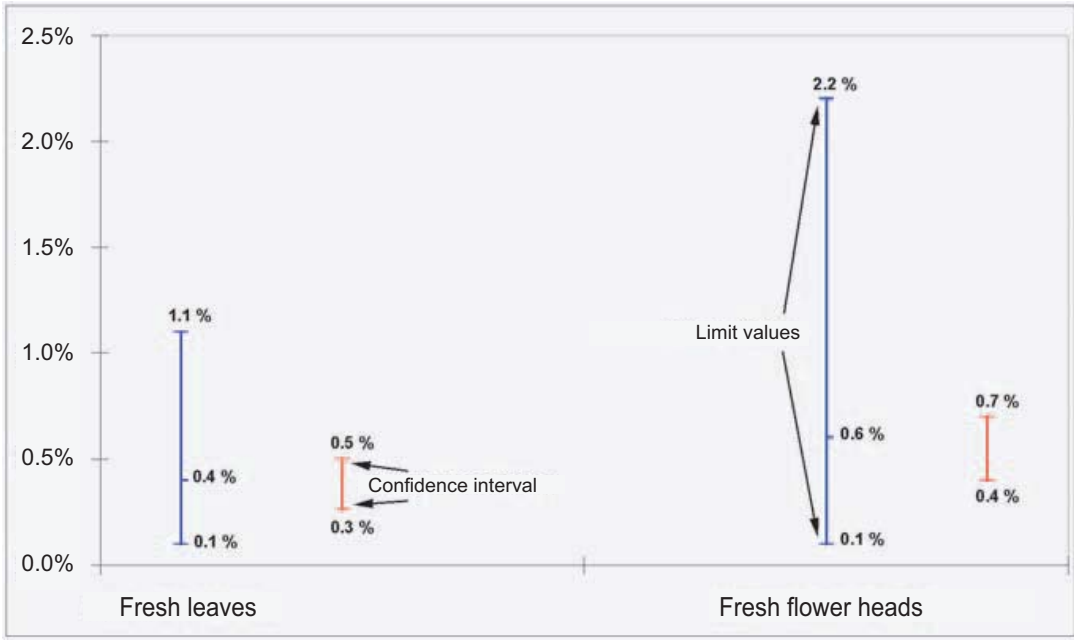
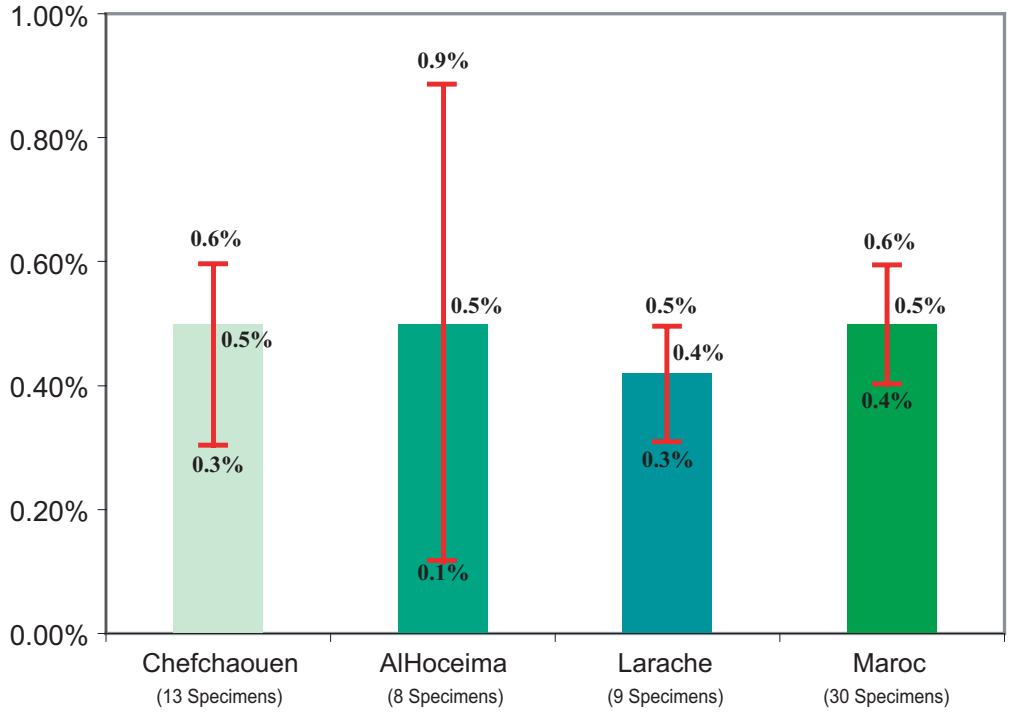


Figure XXII. Average Δ-9-tetrahydrocannabinol content in the leaves and tops of fresh female cannabis plants



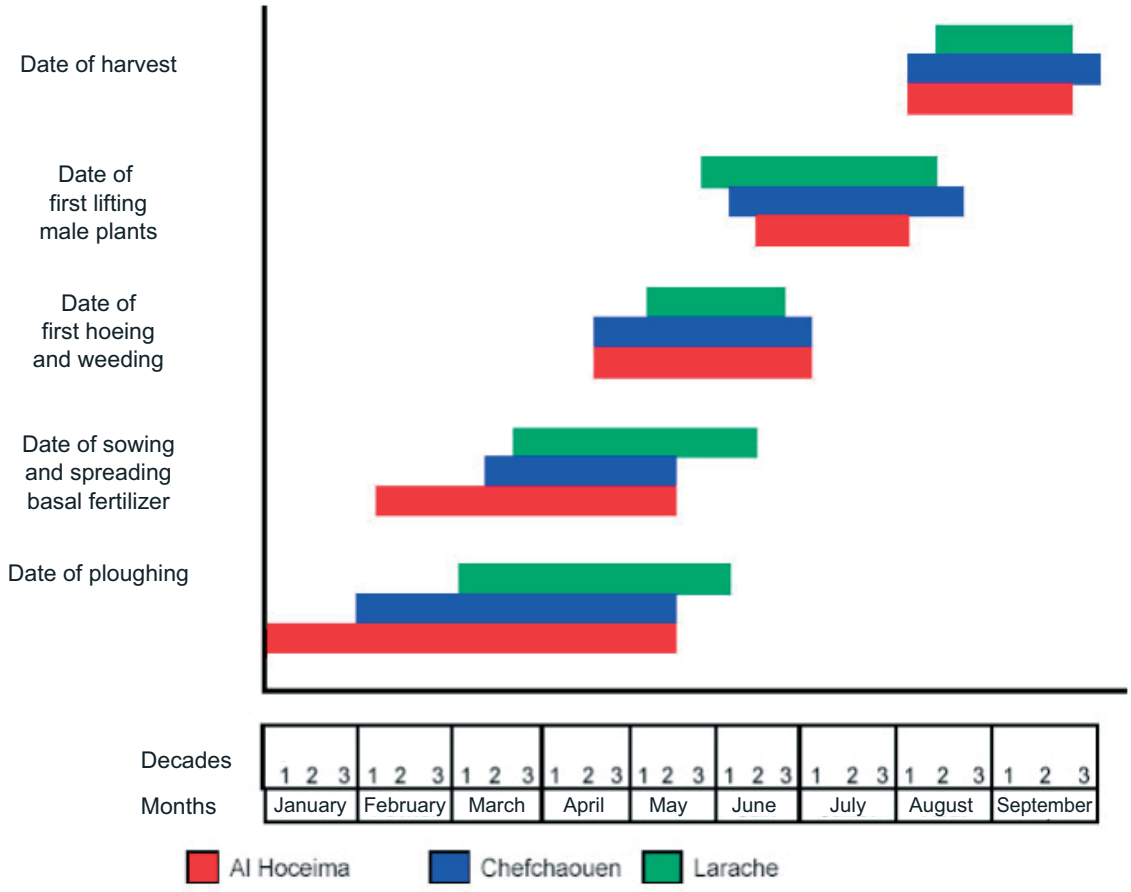
Lastly, a comparison of the average Δ-9-THC levels, including both flowering tops and leaves, and the respective confidence intervals for the three areas (see figure XXIII) show that, at this stage of growth, the cannabis from Chefchaouen and Al Hoceima had slightly higher levels of Δ-9-THC than that from Larache.

Figure XXIII. Differences in the Δ-9-tetrahydrocannabinol content of fresh female cannabis plants from Chefchaouen, Al Hoceima and Larache, with their respective average



It should be emphasized that the comparison of cannabis plants that are still growing is of a merely indicative nature, owing to the fact that sowing dates differed from one plot to the next. In the 2004 season in Larache, Al Hoceima and Chefchaouen, there were differences with respect to the time of ploughing, sowing, weeding, the removal of male cannabis plants and harvesting (see figure XXIV).

Figure XXIV. Management and harvest periods in cannabis cultivation, 2004



Male plants

The present study has demonstrated that, contrary to the widespread belief that male cannabis plants do not secrete the active constituent Δ-9-THC, the compound was, in fact, present in the leaves and tops of male plants.

The leaves of the male plants contained appreciable Δ-9-THC levels, the regional variations of which are shown in figure XXV. The average levels were similar, at about 0.4 per cent.

The values recorded for flowering tops of fresh male plants (figure XXVI) indicated average concentrations of 0.2 per cent for Chefchaouen, 0.3 per cent for Al Hoceima and 0.5 per cent for Larache.

Figure XXV. Average Δ-9-tetrahydrocannabinol content in the leaves of fresh male cannabis plants from three areas in Morocco

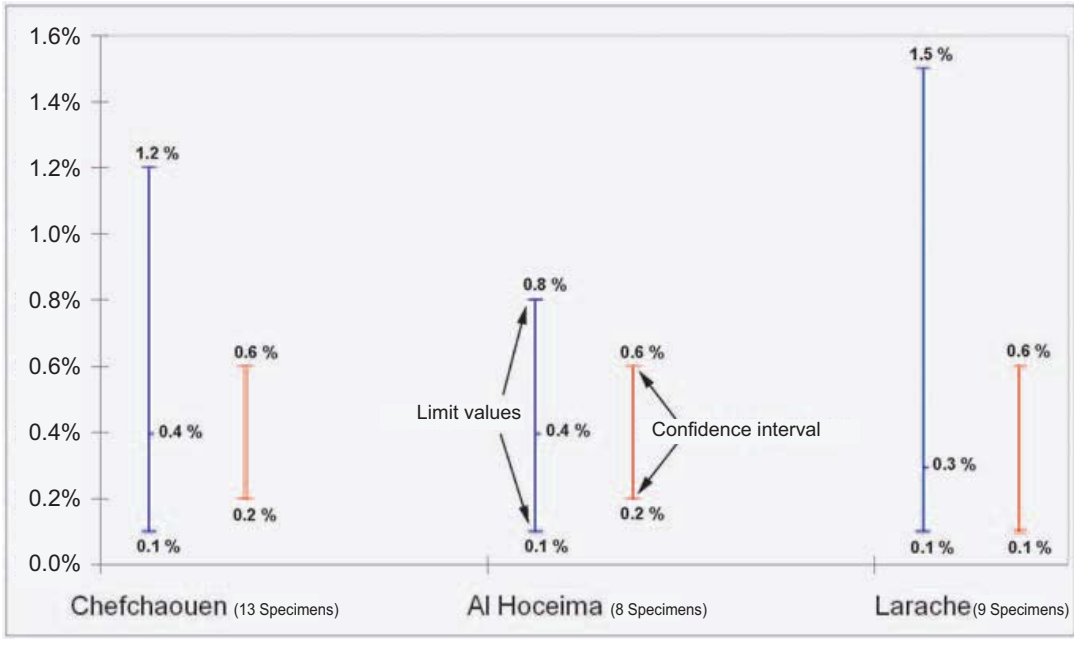
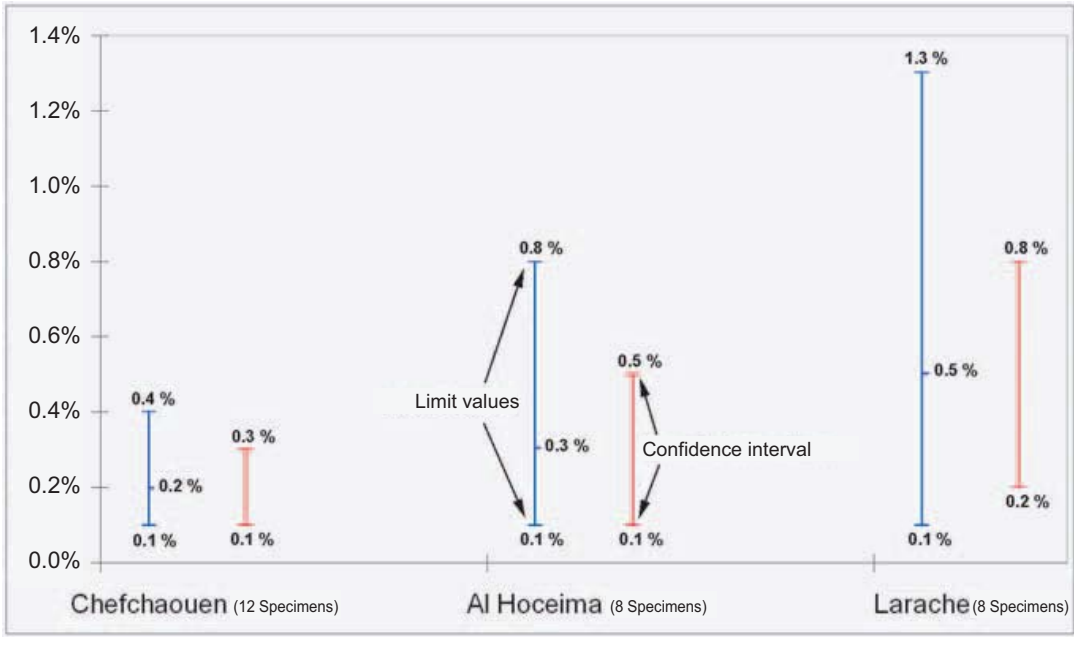
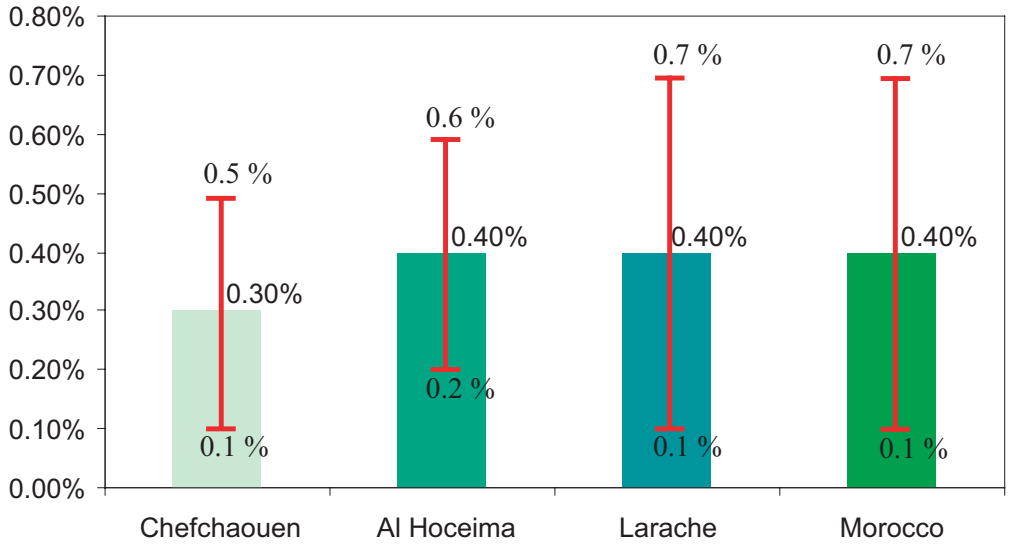


Figure XXVI. Average Δ-9-tetrahydrocannabinol content in the flowering heads of fresh male cannabis plants from Chefchaouen, Al Hoceima and Larache in Morocco



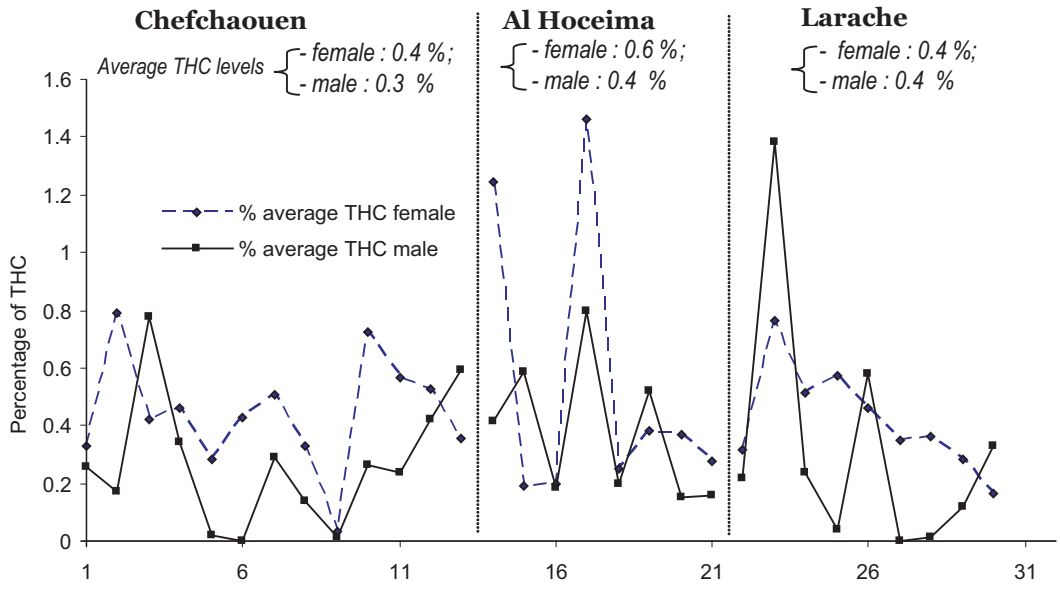
Those results confirm studies [32, 33] that have reported that Δ-9-THC levels are similar in male and female cannabis plants grown under the same conditions. The average general Δ-9-THC level in male cannabis plants has been estimated at 0.4 per cent, and the average levels for tops and leaves were very similar in Chefchaouen, Al Hoceima and Larache (see figure XXVII).

Figure XXVII. Average Δ-9-tetrahydrocannabinol content of fresh male cannabis plants from Chefchaouen, Al Hoceima and Larache in Morocco



Those values, while substantial, were slightly lower than those found in female plants. This is due to the fact that the vegetative cycle of the male plant is longer than that of the female. Moreover, the farmers' practice of removing male plants to prevent pollination of the female plants [21] tends to promote the formation of a variety that is similar to sinsemilla and richer in Δ-9-THC. The two curves in figure XXVIII represent the variations in the average Δ-9-THC level in green male and female cannabis plants from the 30 plots studied.

Figure XXVIII. Average Δ-9-tetrahydrocannabinol content of male and female cannabis plants from Chefchaouen, Al Hoceima and Larache in Morocco



On the other hand, given the random variations recorded in the Δ-9-THC levels in plants from different plots, it was not possible to establish any correlation with bioclimatic factors or cultivation conditions. Analysis showed that neither the leaves nor the inflorescences of two female plants growing 10 metres apart on the same plot consistently presented the same Δ-9-THC level. For that reason, this study gives the average Δ-9-THC concentration in the leaves and flowering tops obtained from two female plants that were analysed separately.

Determination of Δ-9-tetrahydrocannabinol levels in dry cannabis plants

In presenting the analysis results for the dry cannabis plants, it is worth considering the problems resulting from the methods of lifting and sampling such plants. As mentioned already, the dry plants from the 30 plots studied were lifted and randomly combined into bunches, each containing about 30 plants. Whereas the average Δ-9-THC level of the flowering tops were not significantly affected by the height on the plant at which samples were taken, in the case of the leaves, there were non-negligible variations according to sampling height. With respect to the Δ-9-THC content of leaves from the lower third of the dry plants and leaves from the upper third, there was a general tendency towards higher concentrations of Δ-9-THC in the leaves from the upper part (see table 4). Thus, in this study, Δ-9-THC levels in dry cannabis plants were determined based on samples from both the top and the base of the plant.

Table 4. Comparison of the Δ-9-tetrahydrocannabinol content of leaves taken from the lower and upper thirds of the cannabis plant

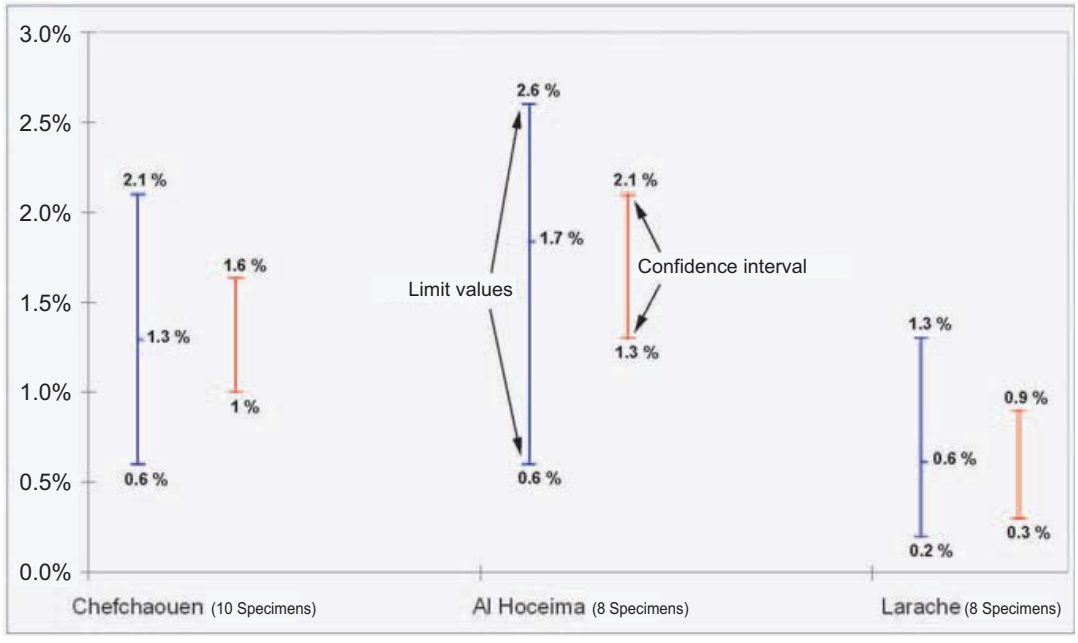
	Plant 1		*Plant 2*	
Sample	*Lower third*	*Upper third*	*Lower third*	*Upper third*
1	0.01	0.09	0.21	0.33
2	0.30	0.39	0.16	0.15
3	0.10	0.11	0.07	0.87
4	0.07	0.21	0.77	1.76

Δ-9-Tetrahydrocannabinol levels in dry cannabis plants

The leaves of dry, mature plants contain Δ-9-THC levels that differ noticeably from one region to another (see figure XXIX). The Al Hoceima area stands out as having the highest concentration, 1.7 per cent on average; it is followed by the Chefchaouen area at 1.2 per cent and the Larache area at 0.6 per cent.

Also in the case of the inflorescences of dry, mature plants (see figure XXX), the highest Δ-9-THC levels were recorded in samples from Al Hoceima (4.1 per cent on average). This confirms the tendency noted in the case of leaves from

Figure XXIX. Average Δ-9-tetrahydrocannabinol content of dried cannabis leaves from three areas in Morocco



that area. The Chefchaouen area, with an average level of 2.1 per cent, is in second position; it is followed by Larache, with an average level of 1.8 per cent.

As in the case of fresh plants, a comparison between the Δ-9-THC levels of the inflorescences and leaves of dry plants (see figure XXXI) revealed that the inflorescences contained levels that were higher by a factor of 2-3. That predictable result was corroborated by a study [34] showing that the Δ-9-THC

Figure XXX. Average Δ-9-tetrahydrocannabinol content of dry cannabis plant tops from three areas in Morocco

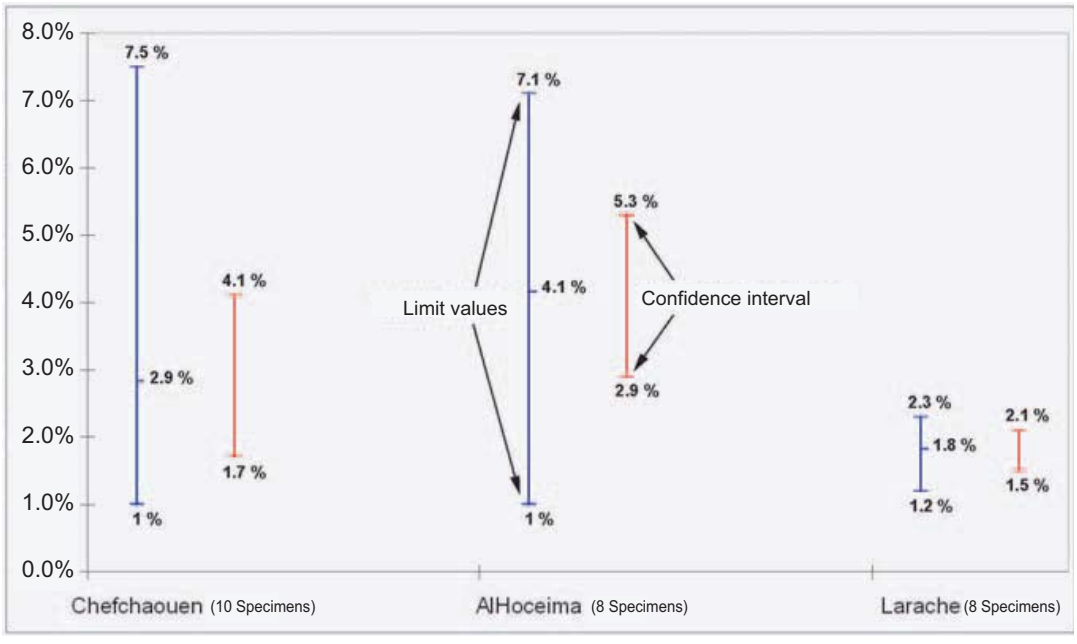
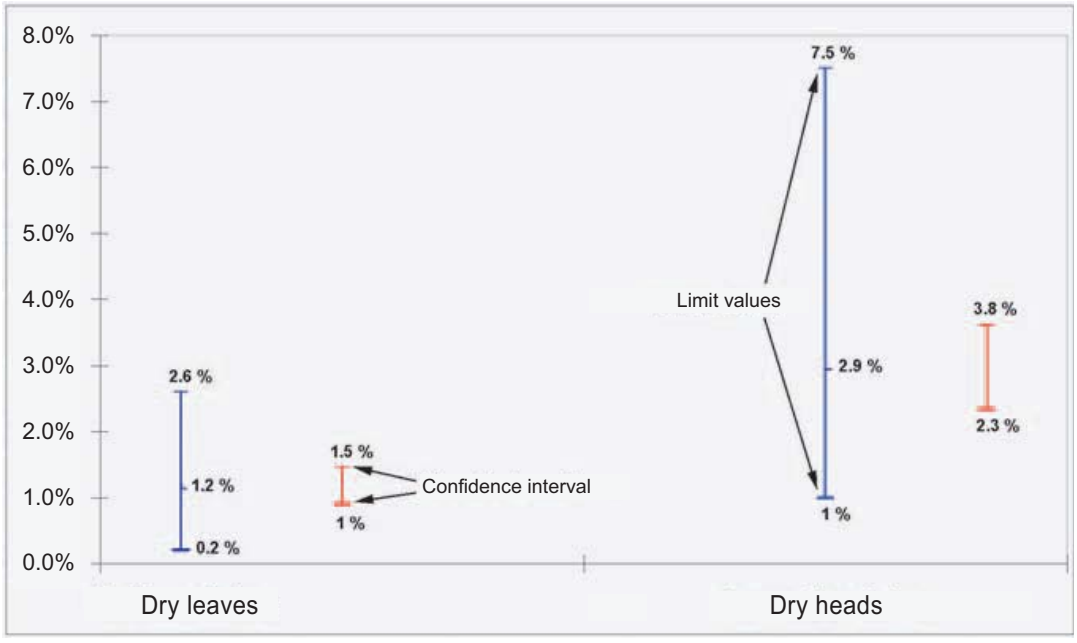


Figure XXXI. Average Δ-9-tetrahydrocannabinol content of leaves and heads of dry cannabis plants (total specimens: 26)



levels of a plant's parts decrease in the following order: bracts, flowers, leaves, stalks, roots and seeds.

More generally, the average Δ-9-THC level in the inflorescences and leaves of the dry plants analysed varied within a range of 0.7-4.8 per cent, and most of the plants had a Δ-9-THC level higher than 1 per cent. Larache was notable for the fact that three of the plots produced cannabis low in Δ-9-THC (<1 per cent), while in Al Hoceima, a relatively high concentration (>3 per cent) was recorded at four plots. Cannabis plants grown in Chefchaouen were characterized by intermediate levels of Δ-9-THC (1-3 per cent). Only one plot in Chefchaouen had cannabis with a fairly high Δ-9-THC level (4.8 per cent).

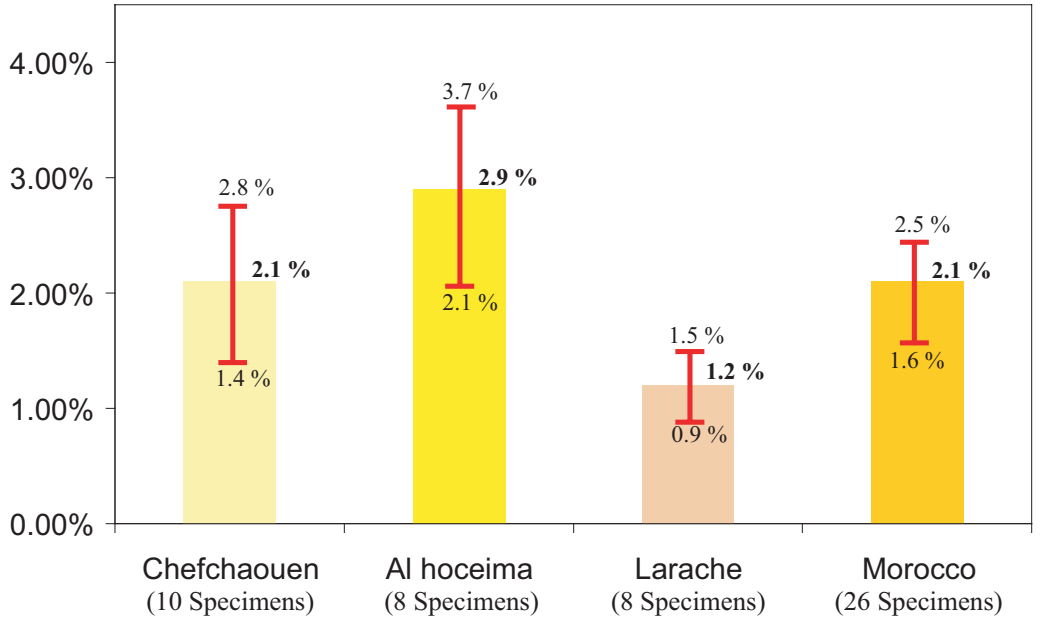
It is clear from figure XXXII, which shows the Δ-9-THC levels for the three areas studied, that there is a marked difference between the different crops. Calculating the average Δ-9-THC level in each area, and taking into account the respective confidence interval, a ranking can be established headed by Al Hoceima and Chefchaouen, the two areas where the practice of cannabis cultivation is long-standing with average Δ-9-THC levels of 2.9 per cent and 2.1 per cent, respectively, followed by Larache, where the average Δ-9-THC level is below 1.2 per cent. The overall average Δ-9-THC level was 2.1 per cent.

The trend in the Δ-9-THC levels noted in dry female plants confirms the above-mentioned results for fresh female plants.

Influence of irrigation on Δ-9-tetrahydrocannabinol levels

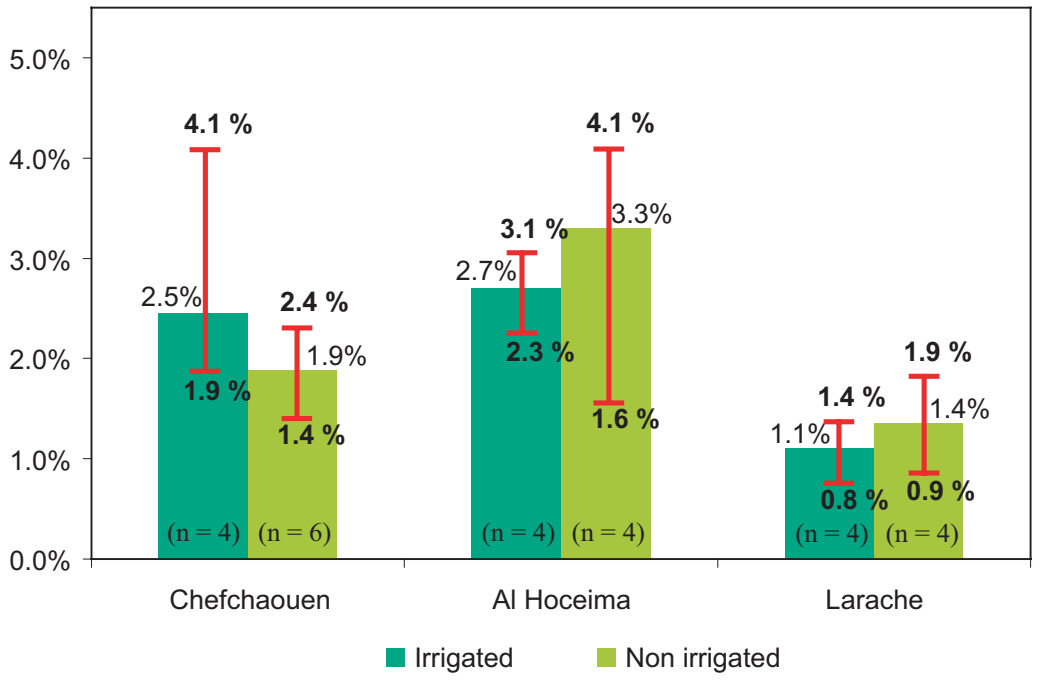
It proved difficult to establish a relationship between the results obtained and the state of irrigation of the land under cannabis cultivation. The average Δ-9-THC levels for dry cannabis leaves and tops in the three regions under

Figure XXXII. Differences in Δ-9-tetrahydrocannabinol in dry cannabis plants from three regions in Morocco



consideration varied according to whether irrigation was used, but in an inconsistent manner (see figure XXXIII). In Al Hoceima and Larache, the Δ-9-THC levels were higher in the unirrigated areas than in the irrigated ones. The average Δ-9-THC levels ranged from 2.7 per cent to 3.3 per cent in Al Hoceima and from 1.1 per cent to 1.4 per cent in Larache. In Chefchaouen, however, the average levels did not conform to that pattern; they were higher in the irrigated areas (2.5 per cent) than in the unirrigated ones (1.9 per cent).

Figure XXXIII. Influence of irrigation on Δ-9-tetrahydrocannabinol levels



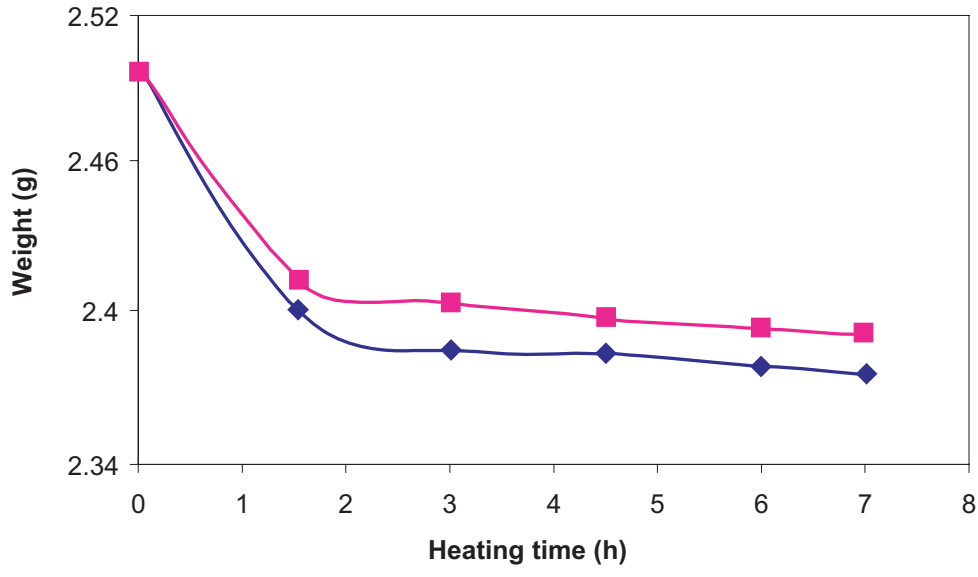
In order to better establish a correlation between irrigation and average Δ-9-THC content, it would be necessary to study a much larger number of samples covering the three areas in their entirety and to take into account factors such as rainfall, sowing periods, bioclimatic stages, the use of phytosanitary products and fertilizers and the genotype of the sown seeds.

Determination of Δ-9-tetrahydrocannabinol levels in powdered cannabis

(a) Effect of drying on the assessment of Δ-9-tetrahydrocannabinol levels of cannabis

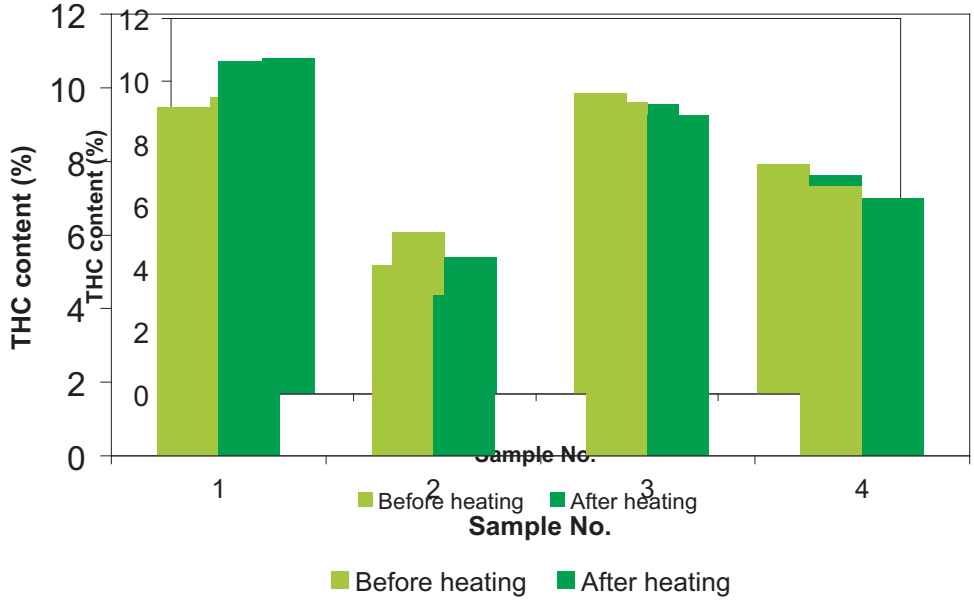
The drying of cannabis samples before determination of their Δ-9-THC content has been described by several authors [11, 24 and 27]. The purpose of the process, which consists of heating at a temperature below 70° C until a constant sample weight is achieved, is complete dehydration in order to achieve greater accuracy. However, heating always entails the risk of denaturing the product through the conversion of Δ-9-THC into CBN. The effect of drying cannabis at 70° C on the behaviour of Δ-9-THC and thus on the accuracy of the concentration calculations was examined in this study. Two samples of powder with an initial weight of 2.5 g were heated at a temperature of 70° C for seven hours, and the loss of weight over time was checked every 90 minutes (see figure XXXIV). The loss of weight was 4 per cent after three hours of drying, and the mass stabilized around that level during the next four hours.

Figure XXXIV. Variations in the mass of two samples of powdered cannabis when heated at 70° C



The effects of this reduction in weight on the calculations of the Δ-9-THC level were then assessed. The tests carried out for that purpose consisted of determining the Δ-9-THC concentrations in the powder before and after drying for seven hours at 70° C. The results of some of those tests (see figure XXXV)

Figure XXXV. Influence of drying on the Δ-9-tetrahydrocannabinol content of powdered cannabis

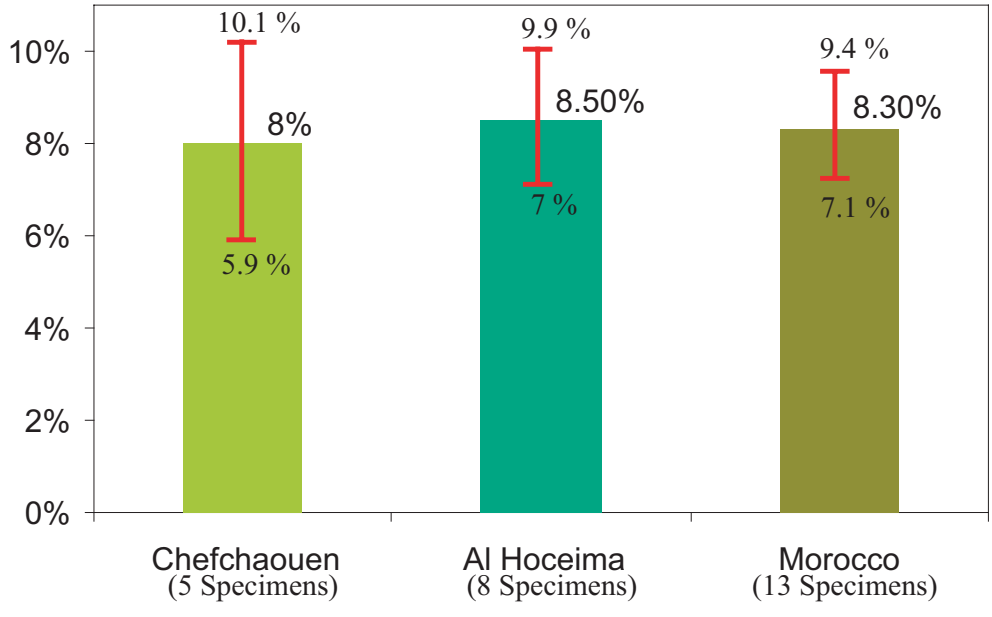


show that drying had little effect on the Δ-9-THC concentrations in the powder. That was probably due to the fact that the powder had just been prepared and its humidity level was very low: slightly more than 4 per cent.

(b) Δ-9-Tetrahydrocannabinol levels in powdered cannabis

The cannabis powder samples studied came exclusively from Al Hoceima and Chefchaouen, where the conversion of dry cannabis into powder form is a long-established practice. The Δ-9-THC levels in the cannabis powder analysed

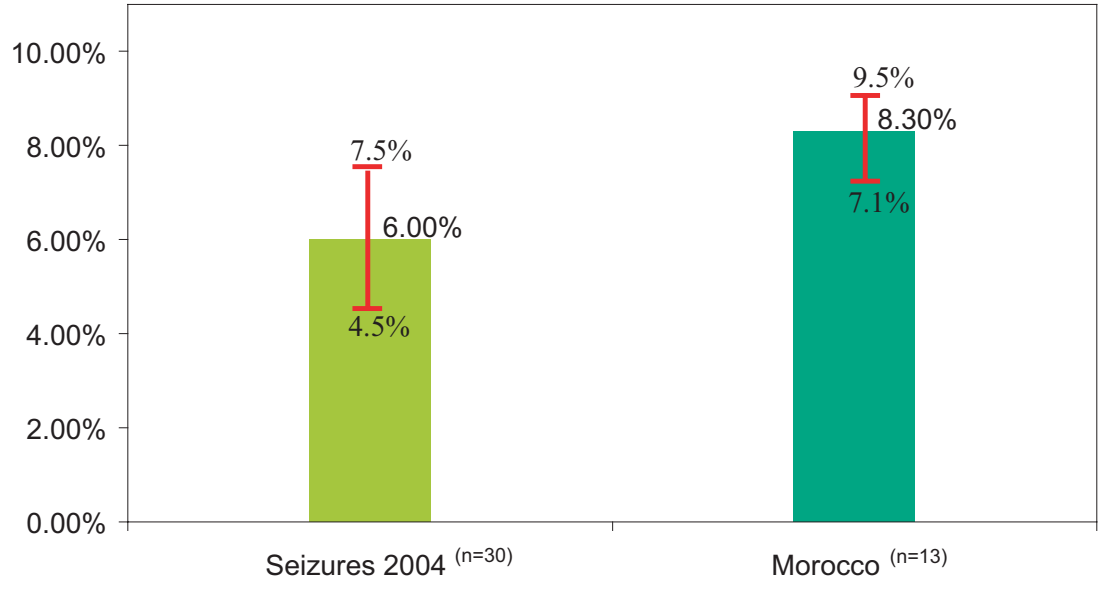
Figure XXXVI. Δ-9-Tetrahydrocannabinol levels in powdered cannabis: range and average



were found to be between 5.5 per cent and 11.3 per cent, with an overall average estimated at 8.3 per cent. The powders from plots in Al Hoceima had an average Δ-9-THC level of 8.5 per cent, slightly higher than those from Chefchaouen, the average Δ-9-THC level of which was 8 per cent. Figure XXXVI shows the variations in the Δ-9-THC levels in powdered cannabis from Chefchaouen and Al Hoceima, together with the overall average Δ-9-THC level.

It should be noted that this average level of Δ-9-THC in freshly prepared powdered cannabis, at 8.3 per cent, was higher than the estimated Δ-9-THC levels (of 6 per cent) in samples from 30 consignments of cannabis resin seized during 2004 by the Gendarmerie Royale (see figure XXXVII). This difference may be due to the effects of the methods used in preparing the powder, adulteration prior to seizure and/or the conditions under which the plants and the resin blocks had been stored for various periods of time.

Figure XXXVII. Average Δ-9-tetrahydrocannabinol level of the powdered cannabis analysed in the present study and that of samples of cannabis resin seized in 2004



Evolution of Δ-9-tetrahydrocannabinol levels through the various stages

Figure XXXVIII illustrates the development of Δ-9-THC in the crops grown on the 13 plots which supplied the three specimen types: fresh cannabis plants, dry cannabis plants and powdered cannabis. It shows that, in each region, the Δ-9-THC levels increased markedly as the plant grew and was then converted into powder.

The estimated average Δ-9-THC level in cannabis was 0.5 per cent in its fresh plant state and 2.1 per cent in its dry plant state. Conversion of the plant to powdered form was accompanied by a marked increase in its Δ-9-THC level, to 8.3 per cent, probably because of the substantial contribution made by the inflorescences and the resin of the plant (see figure XXXIX).

Figure XXXVIII. Evolution of Δ-9-tetrahydrocannabinol levels in cannabis crops from two areas in northern Morocco

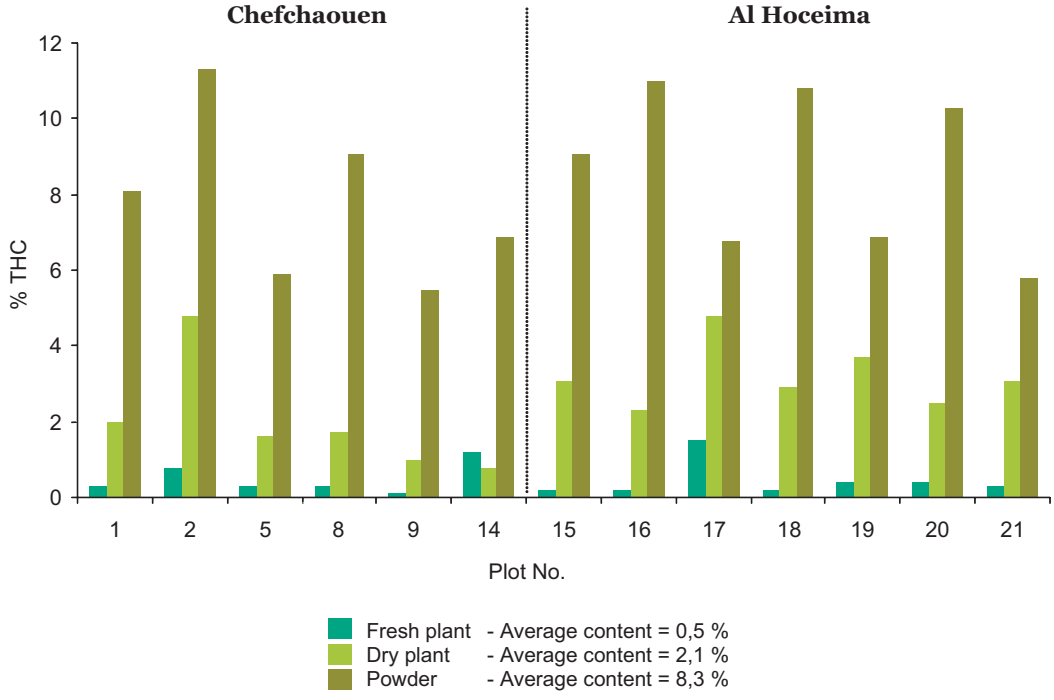
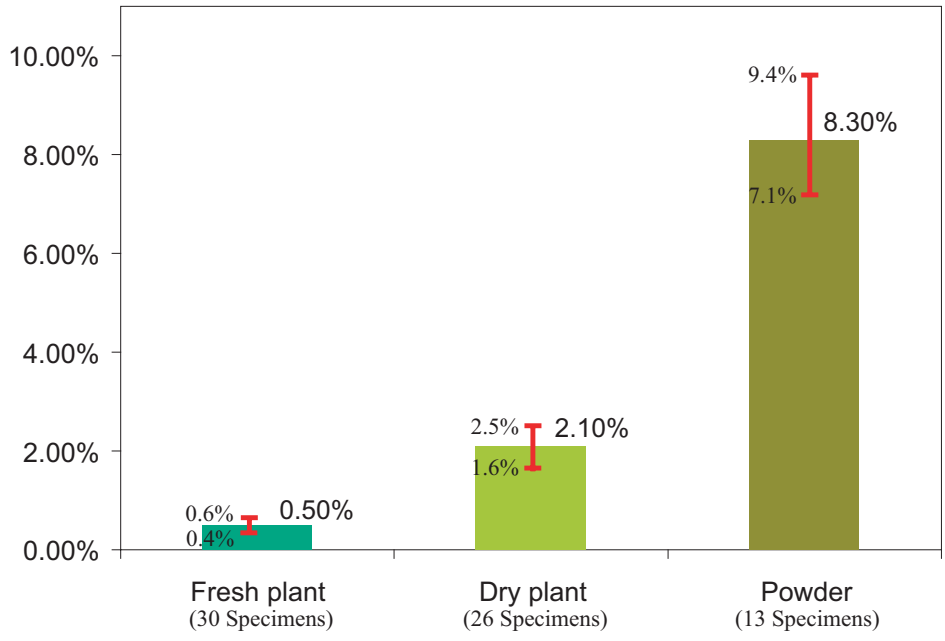


Figure XXXIX. Evolution of Δ-9-tetrahydrocannabinol levels at the fresh plant, dry plant and powdered cannabis stages



Conclusions

The first survey conducted in northern Morocco, in 2003, yielded socio-economic data about the territories where cannabis cultivation has been prevalent for many years and about the recently established cultivation areas. The second survey,

conducted in the Moroccan Rif during 2004, had a different purpose: to assess the quality of local cannabis crops. Three areas, accounting for more than 75 per cent of Morocco's cannabis production in 2004, were selected for the study: Chefchaouen and Al Hoceima, where cannabis cultivation had been a long-standing practice, and Larache, where cannabis had only been cultivated for two decades.

Field studies of cannabis cultivation provide socio-economic data on production, yields and income, among other things, but only the laboratory analysis of cannabis crops can provide the information on chemical composition and levels of psychoactive constituents making it possible to classify them as drug type or fibre type. The analytical work carried out on fresh plants, dry plants and powdered plants benefited from the use of fresh specimens, obtained on the day of harvesting or immediately after preparation, in order to minimize any Δ-9-THC transformations as a result of oxidation due to ageing.

Qualitative analyses of cannabis grown in Morocco using HPLC-DAD provided chromatographic profiles giving a clearer picture of the cannabinoid composition of the plant, dominated by the acid forms (CBDA, THCA and CBNA) along with the corresponding decarboxylated forms (CBD, THC and CBN). Qualitative analyses using GC/MS revealed the principal cannabinoids present in trace amounts in Moroccan cannabis. Tetrahydrocannabinol is present as three natural isomers: cis-Δ-9-THC, trans-Δ-9-THC and trans-Δ-8-THC. Its inferior homologues butyl-Δ-9-THC, methyl-Δ-9-THC and propyl-Δ-9-THC were also found. The qualitative study did not, however, reveal any difference in chemical composition between the cannabis crops grown in the three areas in northern Morocco.

The quantitative analysis of the cannabis crops grown in the three areas in northern Morocco was carried out using GC/MS. It focused exclusively on determining the levels of the psychoactive constituent Δ-9-THC in the growing plant, at the stage of maturation and after its reduction to powder, which is the last stage before it is turned into blocks of chira.

The Δ-9-THC levels found were 0.1-1.5 per cent for the growing plant, 0.7-4.8 per cent for the dry plant and 5.5-11.3 per cent for powdered cannabis. Thus, it is clear that the plants progressively gain in Δ-9-THC. Average levels were calculated for each stage: 0.5 per cent for the growing plant, 2.1 per cent for the dry plant and 8.3 per cent for the powder.

It is worth placing those values in a wider context, comparing them with the Δ-9-THC levels found in cannabis seized in various parts of the world. A retrospective study of Δ-9-THC levels in cannabis seized in the United States between 1980 and 1997 [22] pointed to average Δ-9-THC concentrations in samples of cannabis herb within the range 3-4.47 per cent. A study by the European Monitoring Centre for Drugs and Drug Addiction [23], which presents data reported by European countries on Δ-9-THC levels in cannabis herb and resin, should also be noted. According to that study, the most recent information, compiled in 2001 and 2002, points to Δ-9-THC concentrations of 1.6-15.2 per cent in the plant and 2.0-20.6 per cent in the resin.

Analysis of the flowering tops and leaves of male plants confirmed the secretion of Δ-9-THC at different stages of plant growth. Although the values are

slightly lower than those obtained for female plants, they are very significant; they are due to the fact that the vegetative cycle of the male plant is longer than that of the female plant. In addition, a comparison of Δ-9-THC levels in the inflorescences and leaves of dry plants shows that the inflorescences contain higher concentrations of Δ-9-THC by a factor of 2-3.

Lastly, the study shows that in Larache, where cannabis cultivation is relatively recent, the cannabis crop has Δ-9-THC levels lower than those recorded in Al Hoceima and Chefchaouen, where such cultivation is a longer-established practice. In addition to the know-how accumulated by the farmers in the latter two areas over the years, other factors should be taken into consideration when attempting to explain this fact, for example, growing conditions, rainfall, altitude, hours of sunshine, nature of the soil, irrigation, phytosanitary treatment and even the genotype of the seeds sown.

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